A FIXED-BASE VARIABLE-STABILITY CARRIER APPROACH LANDING SIMULATOR (CALS)

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THESIS

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by

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ABSTRACT

The following is a report on the design and construction of a fixed-base variable-stability simulator facility combined with the task of landing to a carrier or runway.

The solution was mechanized on a hybrid computer with the analog computer solving the equations of motion and the digital computer used for storage, control and graphics generation. The display was in the form of a computer-drawn picture on a graphics terminal. Control was by a simulated cockpit placed in front of the display and connected to the analog computer.

Dynamic validation was considered excellent with the modal periods of the simulated aircraft agreeing very closely with those of the actual aircraft.

The visual display was deemed very good as sufficient visual cues were provided to enable consistent landings by experienced pilots.

This project was undertaken not as a design of training aid but rather as a research tool for further studies in control systems, human engineering and aircraft dynamics.

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LIST OF SYMBOLS

b	Wing span, ft
C_D	Drag coefficient
C_L	Lift coefficient
$C_{L_{\dot{\alpha}}}$	Lift coefficient due to rate of change of angle of attack
$C_{L_{\delta it}}$	Lift coefficient due to elevator deflection
C_{L_Q}	Lift coefficient due to pitching
C_l	Rolling moment coefficient
$C_{l_{\delta a}}$	Aileron control effectiveness derivative
$C_{l_{\delta r}}$	Rolling moment coefficient due to rudder deflection
C_{l_P}	Damping in roll derivative
C_{l_R}	Rolling moment coefficient due to yawing
C_m	Pitching moment coefficient
$C_{m_{\dot{\alpha}}}$	Angle of attack damping derivative
$C_{m_{\delta it}}$	Elevator control effectiveness derivative
C_{m_Q}	Pitch damping derivative
C_n	Yawing moment coefficient
$C_{n_{\delta a}}$	Aileron yaw derivative
$C_{n_{\delta r}}$	Rudder control effectiveness derivative
C_{n_P}	Yawing cross derivative
C_{n_R}	Damping in yaw derivative
C_Y	Side force coefficient

$C_{Y_{\delta a}}$	Side force coefficient due to aileron deflection
$C_{Y_{\delta r}}$	Side force coefficient due to rudder deflection
C_{Y_p}	Side force coefficient due to rolling
C_{Y_R}	Side force coefficient due to yawing
$\bar{c}$	Wing chord, ft
$F_{X_{aero}}$	Aerodynamic force in X stability axis direction, lb
F_{X_s}	Total force in X stability axis direction, lb
F_{X_w}	Total force in X wind axis direction, lb
$F_{Y_{aero}}$	Aerodynamic force in Y stability axis direction, lb
F_{Y_s}	Total force in Y stability axis direction, lb
F_{Y_w}	Total force in Y wind axis direction, lb
$F_{Z_{aero}}$	Aerodynamic force in Z stability axis direction, lb
F_{Z_s}	Total force in Z stability axis direction, lb
F_{Z_w}	Total force in Z wind axis direction, lb
g	Acceleration due to gravity, 32.2 ft/sec^2
I_{xx}	Moment of inertia about X body axis, slug-ft^2
I_{xz}	Cross product of inertia, slug-ft^2
I_{yy}	Moment of inertia about Y body axis, slug-ft^2
I_{zz}	Moment of inertia about Z body axis, slug-ft^2
L	Rolling moment about body axis, ft-lb
L_s	Rolling moment about stability axis, ft-lb
M	Pitching moment about body axis, ft-lb
M_s	Pitching moment about stability axis, ft-lb
m	Mass of the aircraft, slug

N	Yawing moment about body axis, ft-lb
N_s	Yawing moment about stability axis, ft-lb
P	Rolling rate about body axis, rad/sec
P_s	Rolling rate about stability axis, rad/sec
$\overline{P}_s$	Normalized rolling rate about stability axis
Q	Pitching rate about body axis, rad/sec
Q_s	Pitching rate about stability axis, rad/sec
$\overline{Q}_s$	Normalized pitching rate about stability axis
q	Free stream dynamic pressure, lb/ft^2
R	Yawing rate about body axis, rad/sec
R_s	Yawing rate about stability axis, rad/sec
$\overline{R}_s$	Normalized yawing rate about stability axis
S	Aerodynamic reference area, ft^2
$\dot{S}_x$	$\dot{X}$
$\dot{S}_y$	$\dot{Y}$
$\dot{S}_z$	$\dot{Z}$
T	Thrust of aircraft, lb
V	Velocity of aircraft, ft/sec
X	X inertial coordinate of aircraft, ft
Y	Y inertial coordinate of aircraft, ft
Z	Z inertial coordinate of aircraft, ft
α	Angle of attack, deg
β	Angle of sideslip, deg
δ_a	Aileron deflection angle, deg
δ_{it}	Elevator deflection angle, deg
δ_r	Rudder deflection angle, deg
ϕ	Euler roll angle, deg

ψ	Euler yaw angle, deg
θ	Euler pitch angle, deg
$\dot{( )}$	d( )/dt

ACKNOWLEDGEMENTS

The Author wishes to express his appreciation to: Lieutenant (jg) Michael Redlin, Assistant Professor of Aeronautics, for his invaluable assistance and guidance throughout the entire program; Robert Limes, William Thomas and Al Wong, of the Department of Electrical Engineering Computer Laboratory, for their assistance in the writing and running of the program.

I. INTRODUCTION

The purpose of this project was to construct a multiple task simulator, an inherent quality of which had to be the ease of its extension as a research tool to various real world problems that arise. In addition, the use of interactive computer graphics would be studied as a means of visual display for the simulator. The decision was made to design the simulator to the initial task of approach and landing to an aircraft carrier deck.

The hub of the simulator system is a hybrid computer, part digital, part analog. The analog computer solved the equations of motion while the digital computer was used for control, storage and graphic build-up. The display was handled by a graphics processor and terminal connected directly to the digital computer. Control of the simulator was through a simulated cockpit placed in front of the graphic display, with stick and throttle outputs tied directly to the analog. This then formed the control loop as diagrammed in Figure 1.

At the beginning, a decision on the allocation of equipment functions had to be made. Several all-digital moving-base simulators were already constructed [Ref. 1]. As space, money and time were limited, moving base was out of the question but a pure digital solution was not. On the other hand the department already had a "Mini Link" Simulator utilizing an all analog solution. However, due to the lack of non-linear equipment and the need for generating a visual perspective display, the pure analog solution could not be implemented. Then too, the digital solution was too slow for the needed integration and did not provide for a pilot-station computer interface. The obvious solution was the

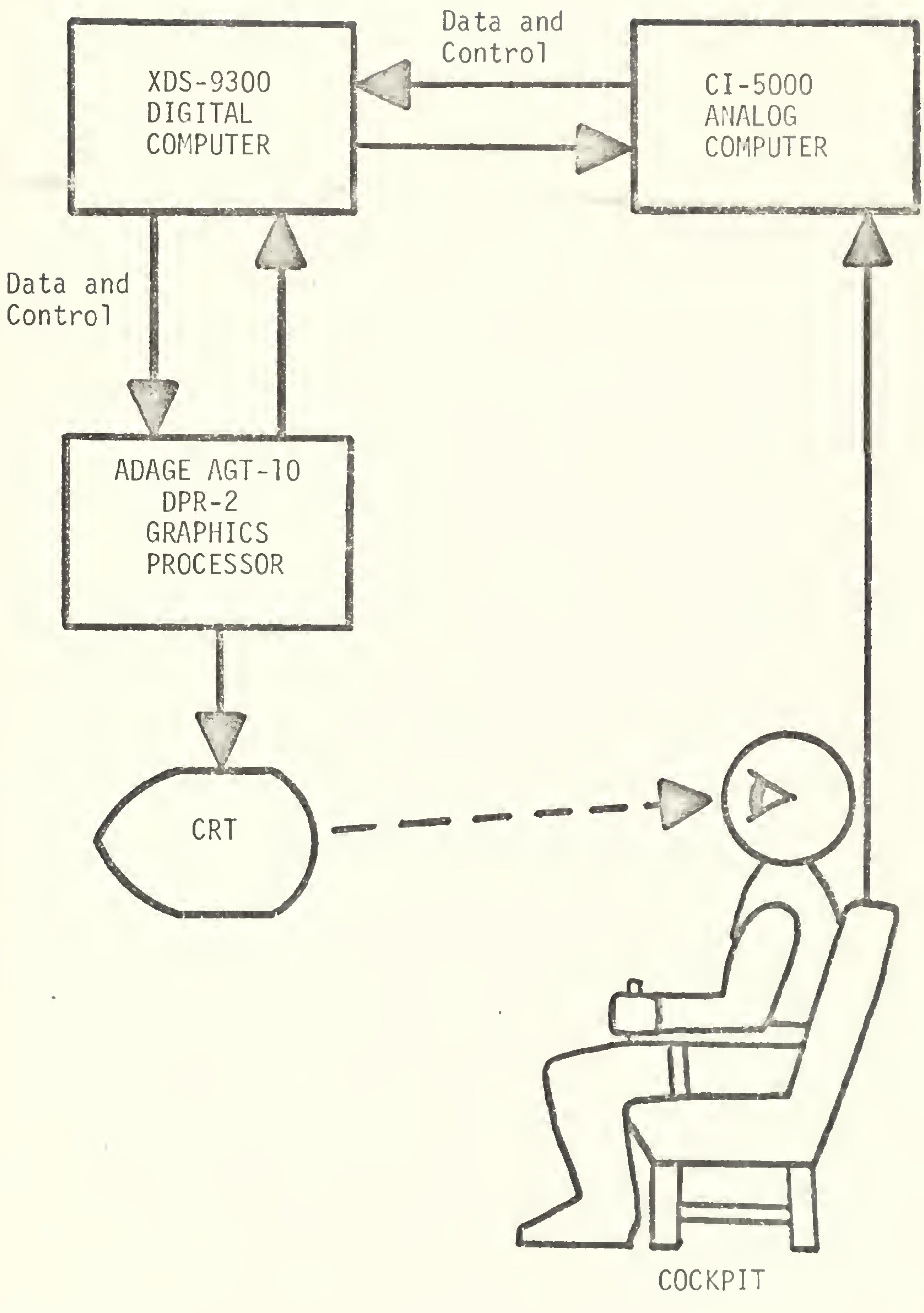


Figure 1. Lines of Communications.

hybrid computer. The non-linearities of the aircraft coefficients, the resolution of the forces and moments and the generation of the display would be tasked to the digital computer. The integration of the equations of motion and the interfacing would be done by the analog. In this manner the best features of both computers could be utilized.

The display would be a computer-drawn picture on a graphics terminal connected to the digital computer. Construction of the picture would be done by the digital computer while the display and refresh would be done by the graphic digital processor.

The "cockpit" was simply a seat and attached controls placed in front of the graphics CRT. Stick and throttle outputs from the cockpit were then fed directly into the analog computer, thus closing the control loop.

The design features incorporated into the Carrier Approach Landing Simulator (CALS) were:

1. Ability to change the aircraft being simulated
2. Capability of simulating non-linear aerodynamic data
3. Automatic scaling of the analog computer solution
4. Fixed-base inside-out display
5. Ability to expand or change the simulator task
6. Simplicity of setup and operation

II. THE SIMULATOR

The simulator is capable of accurately simulating vehicle dynamic response in conjunction with a dynamic inside-out display with its viewing plane affixed to the vehicle. The analog solution is updated at a rate of 18 samples per second which leads to excellent dynamic response. A new graphic display image is generated at the rate of 18 frames per second with a digital processor refresh rate of 40 frames per second. This leads to a display with virtually no flicker and in general very good graphic qualities.

The simulator was designed to accept the following inputs in the form of punched cards: the coordinates of the runway; the runway constants (glide slope and lens placement); the aircraft constants (eight, moment of inertia, wing area etc.); initial conditions of the problem (initial position, altitude and velocity) the maximum expected range of the state and control variables in the form of scale factors: and the aerodynamic coefficients of the simulated aircraft. The preparation of this data deck is outlined in Appendix F.

The simulator then processes this data, autoscales the analog computer based on the given and self-generated scale factors, sets the potentiometers of the analog and places the initial conditions on the proper integrators. Control of the simulator is then transferred to the pilot who responds as per the displayed instructions. At the completion of a run the simulator analyzes the landing and displays the results. This analysis includes sink rate at touch down, line-up, airspeed and type of landing (crash, bolter or arrested landing on a certain wire). At this time options are offered to either fly again with the same parameters, change the parameters or stop the program.

Besides these options, the operator can suppress printed output if desired, select a yaw damper (ON/OFF) and inhibit translational movement while flying the aircraft. Also, at the disposal of the operator, is an eight-channel strip recorder and an oscilloscope that are patched into the analog computer. This gives the operator the ability to output the time history of any variable he wishes.

The cockpit consists of a chair upon which the throttle and control stick have been mounted. The stick, mounted on the right arm, is a Gemini control stick providing all three controls: yaw, pitch and roll. At the top of the stick is located one of the control buttons used in the control of the program from the pilot station. Mounted on the left arm is a throttle plate containing a small throttle and another control button. The outputs of the cockpit are fed via a wire bundle to the rear of the analog computer for processing.

A complete operating manual is contained in Appendix H.

III. SIX DEGREE OF FREEDOM AIRFRAME EQUATIONS

R.M. Howe [Refs. 2 and 3] discusses three coordinate systems - body, wind, and stability axes - and concludes that the use of wind axes for the translational equations and of body axes for the rotational equations of motion is the best choice. As can be seen from Figure 2, the body axes differ from the stability axes by the aircraft angle of attack, while the stability axes differ from the wind or flight path axes by the side slip angle.

Assuming that the three angular rates of the aircraft (P,Q,R) about the body axis are given, the angular rates about the stability axis (P_s,Q_s,R_s) can be computed (Eqn 101-103).

$$P_s = P \cos \alpha + R \sin \alpha \tag{101}$$

$$Q_s = Q \tag{102}$$

$$R_s = P \sin \alpha + Q \cos \alpha \tag{103}$$

These angular rates can then be normalized using equations 104-106.

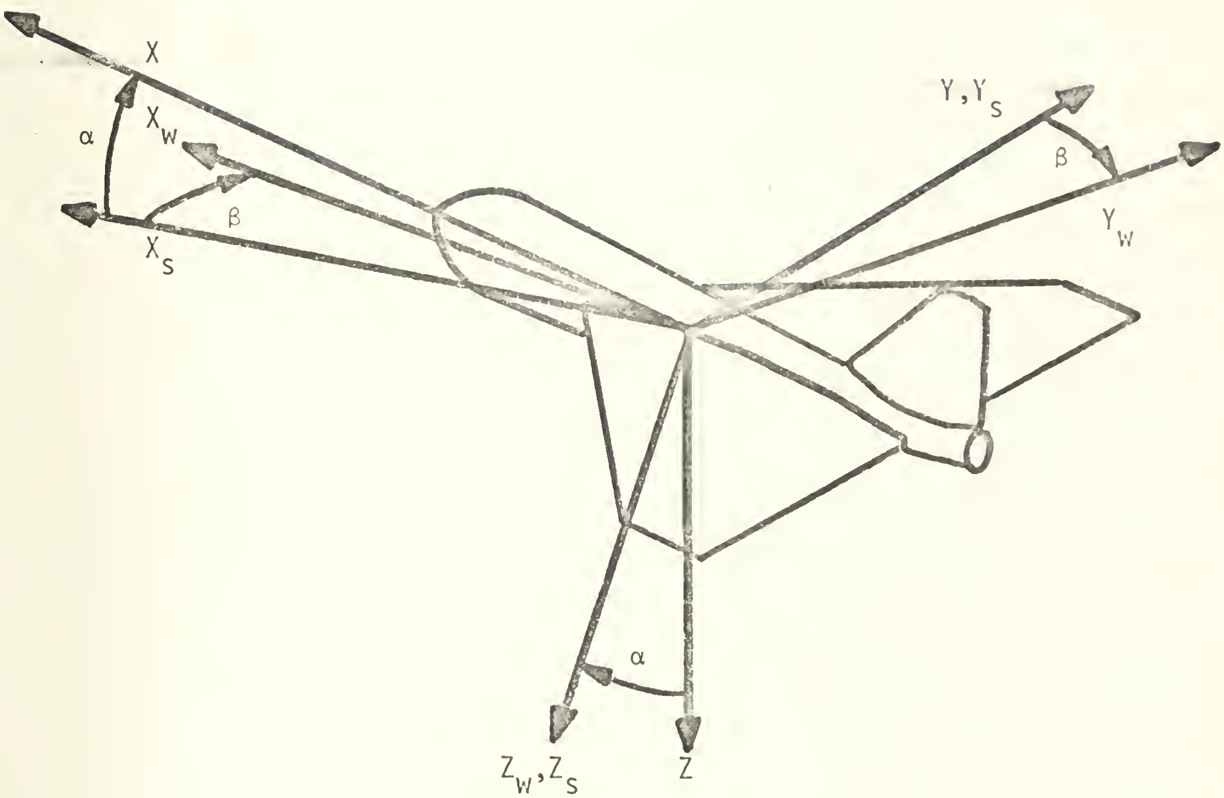
$$\overline{P}_s = \frac{P_s b}{2V} \tag{104}$$

$$\overline{Q}_s = \frac{Q_s b}{2V} \tag{105}$$

$$\overline{R}_s = \frac{R_s b}{2V} \tag{106}$$

The aerodynamic forces expressed along the stability axes can then be calculated (Eqn 107-109).

$$\frac{F_{X_{aero}}}{m} = q \left(\frac{-SC_D}{m} \right) \tag{107}$$



X, Y, Z - Body Axis

X_S, Y_S, Z_S - Stability Axis

X_W, Y_W, Z_W - Wind or Flight Path Axis

Figure 2. Aircraft Coordinate Axis.

$$\frac{F_{Y_{aero}}}{m} = q\left[\frac{SC_Y}{m} + \frac{S\bar{R}_S C_{Y_R}}{m} + \frac{S\bar{P}_S C_{Y_P}}{m} + \frac{SC_{Y_{\delta r}}\delta r}{m} + \frac{SC_{Y_{\delta a}}\delta a}{m}\right] \tag{108}$$

$$\frac{F_{Z_{aero}}}{m} = q\left[\frac{SC_L}{m} + \frac{\bar{Q}_S(-S)C_{L_Q}}{m} + \frac{\dot{\alpha}\bar{C}(-S)C_{L_{\dot{\alpha}}}}{2Vm} + \frac{\delta it(-S)C_{L_{\delta it}}}{m}\right] \tag{109}$$

The forces in the body axes are then resolved into forces in the stability axes (Eqn 110-112). Thrust and the force of gravity are included at this time. Thrust was assumed to have only an X component.

$$\frac{F_{X_S}}{m} = \left(\frac{T}{m} - g \sin \theta\right) \cos \alpha + g \cos \theta \cos \phi \sin \alpha + \frac{F_{X_{aero}}}{m} \tag{110}$$

$$\frac{F_{Y_S}}{m} = g \cos \theta \sin \phi + \frac{F_{Y_{aero}}}{m} \tag{111}$$

$$\frac{F_{Z_S}}{m} = -\left(\frac{T}{m} - g \sin \theta\right) \sin \alpha + g \cos \theta \cos \phi \cos \alpha + \frac{F_{Z_{aero}}}{m} \tag{112}$$

The forces are then resolved from the stability axes to the wind or flight path axes (Eqn 113-115).

$$\frac{F_{X_W}}{m} = \frac{F_{X_S}}{m} \cos \beta + \frac{F_{Y_S}}{m} \sin \beta \tag{113}$$

$$\frac{F_{Y_W}}{m} = \frac{-F_{X_S}}{m} \sin \beta + \frac{F_{Y_S}}{m} \cos \beta \tag{114}$$

$$\frac{F_{Z_W}}{m} = \frac{F_{Z_S}}{m} \tag{115}$$

From these equations the translational equations of motion can be determined. Solving for the derivatives yields equations 116-118.

$$\dot{V} = \frac{F_{X_W}}{m} \tag{116}$$

$$-\dot{\alpha} = \frac{-F_{Z_W}}{mV \cos \beta} + \frac{P_S \sin \beta}{\cos \beta} - Q_S \tag{117}$$

$$-\dot{\beta} = \frac{-F_{X_W}}{mV} + R_S \tag{118}$$

Further, the Euler angular rates can then be calculated (Eqn 119-121).

$$-\dot{\psi} = -\frac{(R \cos \phi + Q \sin \phi)}{\cos \theta} \tag{119}$$

$$-\dot{\theta} = -Q \cos \phi + R \sin \phi \tag{120}$$

$$-\dot{\phi} = -P + \dot{\psi} \sin \theta \tag{121}$$

Now focusing our attention on the moment equations, the three equations about the stability axes can be written as follows (Eqn 122-124).

$$\frac{L_S}{I_{XX}} = q\left[\frac{SbC_l}{I_{XX}} + \frac{\bar{P}_S SbC_{l_P}}{I_{XX}} + \frac{\bar{R}_S SbC_{l_R}}{I_{XX}} + \frac{\delta a SbC_{l_{\delta a}}}{I_{XX}} + \frac{\delta r SbC_{l_{\delta r}}}{I_{XX}}\right] \tag{122}$$

$$\frac{M_S}{I_{yy}} = q\left[\frac{S\bar{c}C_m}{I_{yy}} + \frac{\bar{Q}_S S\bar{c}C_{m_Q}}{I_{yy}} + \frac{\dot{\alpha} S\bar{c}C_{m_{\dot{\alpha}}}}{I_{yy}} + \frac{\delta it S\bar{c}C_{m_{\delta it}}}{I_{yy}}\right] \tag{123}$$

$$\frac{N_S}{I_{ZZ}} = q\left[\frac{SbC_n}{I_{ZZ}} + \frac{\bar{P}_S SbC_{n_P}}{I_{ZZ}} + \frac{\bar{R}_S SbC_{n_R}}{I_{ZZ}} + \frac{\delta a SbC_{n_{\delta a}}}{I_{ZZ}} + \frac{\delta r SbC_{n_{\delta r}}}{I_{ZZ}}\right] \tag{124}$$

These moments are then resolved into the body axes yielding Equations 125-127.

$$\frac{L}{I_{XX}} = \frac{L_S}{I_{XX}} \cos \alpha - \frac{N_S}{I_{ZZ}} \sin \alpha \tag{125}$$

$$\frac{M}{I_{yy}} = \frac{M_S}{I_{yy}} \tag{126}$$

$$\frac{N}{I_{ZZ}} = \frac{L_S}{I_{XX}} \sin \alpha + \frac{N_S}{I_{ZZ}} \cos \alpha \tag{127}$$

The rotational equations of motion can then be written (Equations 128-130).

$$\dot{P} = \frac{(I_{yy} - I_{ZZ})}{I_{XX}} QR + \frac{I_{XZ}(\dot{R} + PQ)}{I_{XX}} + \frac{L}{I_{XX}} \tag{128}$$

$$\dot{Q} = \frac{(I_{zz} - I_{xx})}{I_{yy}} RP + \frac{I_{xz} (R^2 - P^2)}{I_{yy}} + \frac{M}{I_{yy}} \tag{129}$$

$$\dot{R} = \frac{(I_{xx} - I_{yy})}{I_{zz}} PQ + \frac{I_{xz} (\dot{P} - QR)}{I_{zz}} + \frac{N}{I_{zz}} \tag{130}$$

As suggested by Howe [Ref. 2], a simplified method for computing the velocities in the inertial frame yields equations 131-133. This approach uses small angle approximations in its development.

$$\dot{S}_x = V \cos \theta \cos \psi \tag{131}$$

$$\dot{S}_y = V \cos \theta \sin \psi \tag{132}$$

$$\dot{S}_z = V(-\sin \theta + \sin \alpha \cos \theta \cos \phi) \tag{133}$$

The various derivatives that were solved for in the above equations can then be integrated yielding the state variables that were assumed to exist at the start (Eqns 134-145)

$$P = \int \dot{P}\, dt \tag{134}$$

$$Q = \int \dot{Q}\, dt \tag{135}$$

$$R = \int \dot{R}\, dt \tag{136}$$

$$\alpha = \int \dot{\alpha}\, dt \tag{137}$$

$$\beta = \int \dot{\beta}\, dt \tag{138}$$

$$\psi = \int \dot{\psi}\, dt \tag{139}$$

$$\theta = \int \dot{\theta}\, dt \tag{140}$$

$$\dot{\phi} = \int \dot{\phi}\, dt \tag{141}$$

$$V = \int \dot{V}\, dt \tag{142}$$

$$x = \int \dot{S}_x\, dt \tag{143}$$

$$y = \int \dot{S}_y\, dt \tag{144}$$

$$z = \int \dot{S}_z\, dt \tag{145}$$

The equations themselves, when examined, seemingly divide themselves into two groups. One that can be solved by digital means and one that can be solved by the use of the analog computer. In fact this logical division is the one chosen for the simulator.

IV. GRAPHICS PRESENTATION

Since the primary scan during a carrier approach consists of only three things, the "meatball" or the Fresnel Lens Optical Landing System, the aircraft's angle of attack and the line-up with the runway centerline, it was decided to incorporate only these three visual cues into the display.

The angle of attack was represented by an angle of attack indexer situated in the upper right hand corner of the display. Its operation is exactly the same as the one found in the jets/turboprops operating in the Navy today. The indexer has five descrete states as shown in Figure 3.

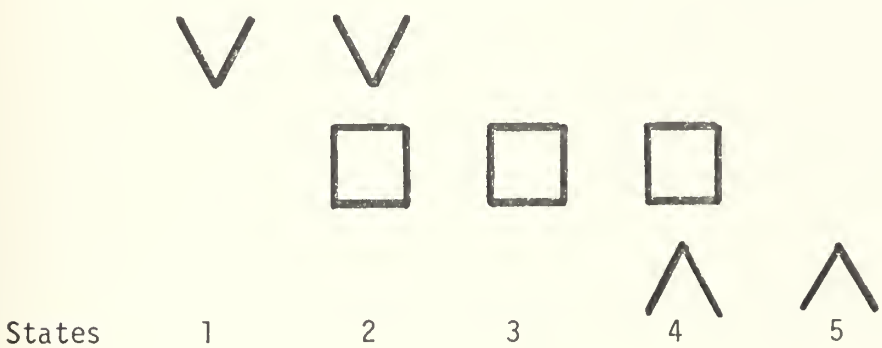


Figure 3. Angle of Attack Indexer States.

Optimum/Landing angle of attack was represented by State 3. As one increases the angle of attack of the aircraft, State 2 would appear indicating the aircraft was a "little slow" and eventually State 1 would appear indicating that the aircraft was "slow". Proceeding the other direction from State 3, that is decreasing the angle of attack, first State 4 would appear indicating the aircraft was a "little fast" and finally State 5 would appear indicating the aircraft was "fast". In

terms of degrees, assuming optimum angle of attack to be 0°, the following would exist:

STATES	RANGE OF AOA
1	Greater than 2.0°
2	Between 1.0° and 2.0°
3	1.0° to -1.0°
4	Between -1.0° and -2.0°
5	Less than -2.0°

The Fresnel Lens is represented by two fixed rectangular boxes for the datum lights and a movable square for the "meatball" as shown in Figure 4.

Figure 4. Centered Meatball.

The operation is again the same as found in the Navy systems. If the "meatball is above the datum bars, as in Figure 5, the aircraft is above the glide slope.

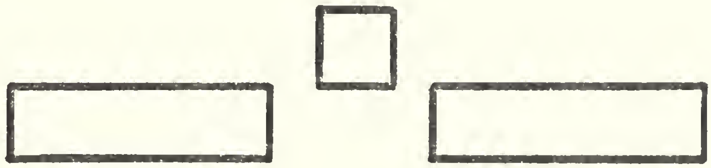


Figure 5. High Meatball.

If the "meatball" is below the datum bars, as in Figure 6, the aircraft is below the glide slope.

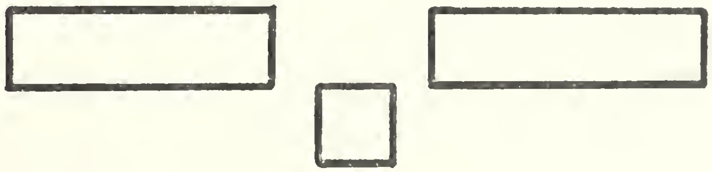


Figure 6. Low Meatball.

The object is to keep the "meatball" centered within the datums. The "meatball" has a 1.5 degree visibility arc centered on the optimum glide slope and will disappear if this is exceeded. Also, once you fly past the lens itself the "meatball" will disappear. However, in this simulation the datums will remain visible at all times, only the "meatball" disappears.

Since the lens is affixed to the carrier/runway in real life, the size of the presentation will change. However, since the vast majority of flight cues are absent in the simulator, the size of the simulated lens will remain fixed. This presentation is placed in the upper left hand corner of the display.

The line-up cue is received from the picture of the runway itself. The picture shown is as if a movie camera were affixed to the nose (X-axis) of the aircraft. The field of view is a square with an angular limit of plus or minus 18.5 degrees in the vertical and horizontal directions. Within this window lies the horizon and the runway outline. Tic marks at 0° and plus and minus 10° of pitch are given along the left side of the window. As the aircraft maneuvers through space the runway and horizon move dynamically as if filmed by the movie camera. The complete display is shown in Figure 7.

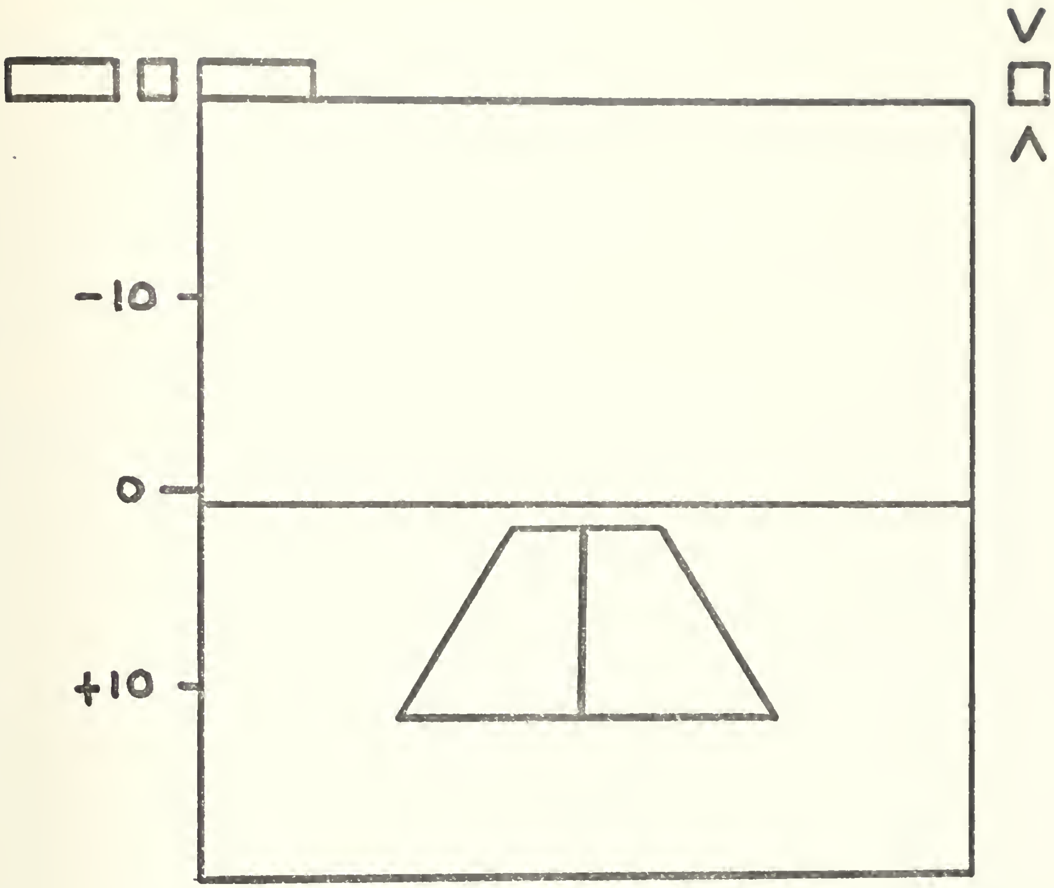


Figure 7. The Complete Graphics Display.

V. PROCESSING THE DISPLAY

The processing of the angle of attack indexer is straightforward as it is solely a function of the angle of attack of the aircraft. A simple test of the angle of attack will yield one of the five previously mentioned states.

The Fresnel Lens or "meatball" is again a simple task to process. Knowing the x-coordinate and the z-coordinate of the aircraft and the x-coordinate of the lens, the glide slope angle can be calculated.

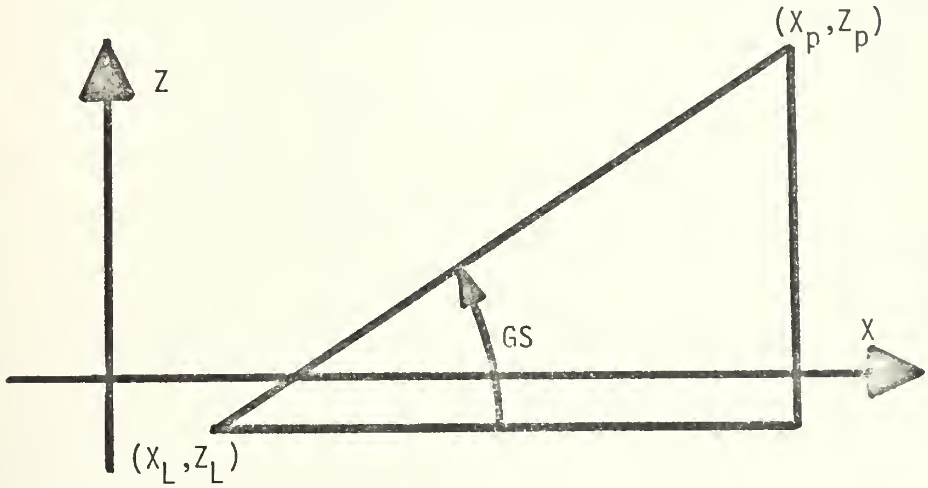


Figure 8. Glide Slope Computation.

The angle GS in Figure 8 is the glide slope angle while (X_p, Z_p) and (X_L, Z_L) are the coordinates of the plane and lens respectively.

$$GS = \tan^{-1}((Z_p - Z_L)/(X_p - X_L))$$

Angle GS is then calculated and compared to the optimum glide slope, and the "meatball" is drawn accordingly. If GS is greater than the allowable limits, or if $X_p < X_l$, the "meatball" is not displayed.

The processing of the runway is by far the most complicated. How to transform a three-dimensional object like the runway into a two-dimensional object capable of being displayed on the screen of a CRT?

The answer was found in two works, one by L.G. Roberts [Ref. 3] and the other by R.B. Desens [Ref. 4]. Roberts introduces the idea of a homogeneous coordinate system which introduces a fourth coordinate or variable scale factor. He also constructs a single transformation matrix for all points. This transformation matrix (H-Matrix) is a product of five matrices: rotation, translation, perspective, another translation and scale. Each point is post-multiplied by the H-Matrix and then the scale factor is divided out yielding the display coordinates. Desens used this to process pictures of an aircraft carrier from various positions. He also reduced the H-Matrix to a product of three individual matrices as shown in Figure 9.

$$H = \underbrace{\begin{bmatrix} A_1 & A_2 & A_3 & 0 \\ B_1 & B_2 & B_3 & 0 \\ C_1 & C_2 & C_3 & 0 \\ X_T & Y_T & Z_T & 1 \end{bmatrix}}_{\text{Object Axis Rotation (Euler Angles) Viewing Plane Translation}} \underbrace{\begin{bmatrix} AA_1 & AA_2 & AA_3 & 0 \\ BB_1 & BB_2 & BB_3 & 0 \\ CC_1 & CC_2 & CC_3 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}}_{\text{Viewing Plane Orientation}} \underbrace{\begin{bmatrix} 1 & -Y_0/F & -Z_0/F & -S/F \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & Y_0 & Z_0 & S \end{bmatrix}}_{\text{Perspective Scale Offset}}$$

Figure 9. H-Matrix

Figure 10 has the two coordinate systems, that of the earth and that of the aircraft. The viewing plane or camera is placed on the nose of the aircraft while the runway is oriented in the object or earth reference system. The first matrix is made up in part by the direction cosines of the Euler angle rotation of the object (runway). In this case the runway is fixed. The Euler angle direction cosines are given below and are based on the rotations shown in Figure 11.

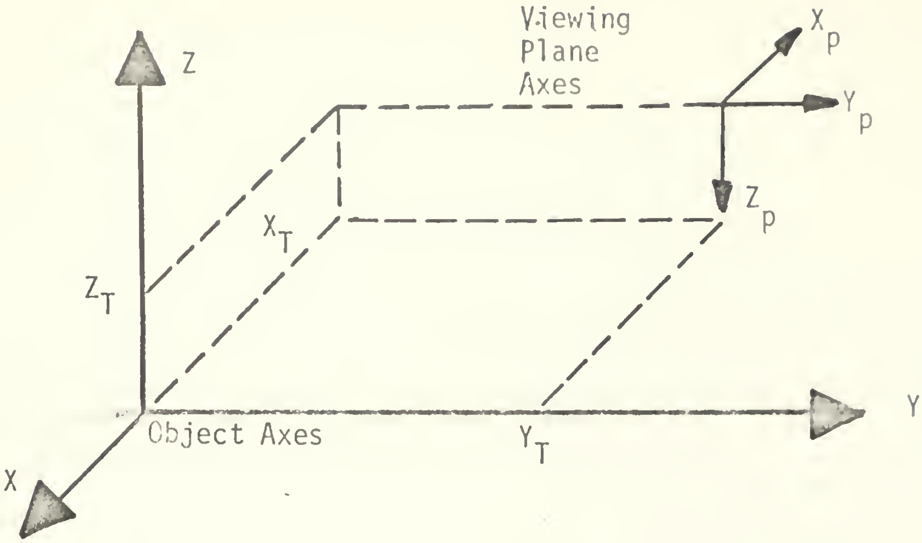


Figure 10. Graphic Coordinate System.

Euler Angle Direction Cosines

$A_1 = \cos\beta \cos\alpha$

$A_2 = \cos\beta \sin\alpha$

$A_3 = -\sin\beta$

$B_1 = -\cos\gamma \sin\alpha + \sin\gamma \sin\beta \cos\alpha$

$B_2 = \cos\alpha \cos\gamma + \sin\gamma \sin\beta \sin\alpha$

$B_3 = \sin\gamma \cos\beta$

$C_1 = \sin\gamma \sin\alpha + \cos\gamma \sin\beta \cos\alpha$

$C_2 = -\sin\gamma \cos\alpha + \cos\gamma \sin\beta \sin\alpha$

$C_3 = \cos\beta \cos\gamma$

Order of Rotation
α, β, γ

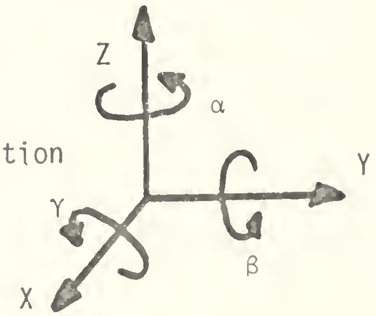


Figure 11. Euler Angle Rotation.

X_T, Y_T and Z_T are the translation distances between the two axis systems.

$X_T = X_{object} - X_{view\ plane}$

$Y_T = Y_{object} - Y_{view\ plane}$

$Z_T = Z_{object} - Z_{view\ plane}$

The second matrix is made up entirely of the viewing-plane-orientation direction cosines. The direction cosines are given below in terms of the Euler angles of the aircraft.

$AA_1 = \cos\psi \cos\theta$

$AA_2 = \sin\psi \cos\phi - \cos\psi \sin\theta \sin\phi$

$AA_3 = \sin\psi \sin\phi + \cos\psi \sin\theta \cos\phi$

$BB_1 = -\cos\theta \sin\psi$

$BB_2 = \cos\psi \cos\phi + \sin\theta \sin\psi \sin\phi$

$BB_3 = \cos\psi \sin\phi - \sin\psi \sin\theta \cos\phi$

$CC_1 = -\sin\theta$

$CC_2 = -\cos\theta \sin\phi$ Order of Rotation

$CC_3 = \cos\theta \cos\phi$ ψ (yaw), θ (pitch), ϕ (roll)

The third matrix consists of the offset option, Z_0 and Y_0, which allows one to look at an offset portion of the viewing plane. This option is not used on this display. The matrix also contains the scale factor (S) and the focal length (F). The scale factor is set at 1/2 and the focal length, the distance between the viewer and the viewing plane, is set at 1.5 ft. The field of view is controlled by S and F and is equal to $\tan^{-1}(S/F)$.

A point on the object (X,Y,Z) is converted to homogeneous coordinates by the addition of another scale factor (W) yielding (X', Y', Z',W) where X' = WX, Y' = WY, Z' = WZ. This then is post multiplied by the

H-Matrix yielding (X'', Y'', Z'', W'). The display coordinates of the processed point can then be found by dividing by W'

$Y''' = Y''/W'$

$Z''' = Z''/W'$

The coordinate $X''' = X''/W'$ is an indicator of depth and can be used for depth cues, however, it is not used in this display. Each point of the runway is passed through the H-Matrix yielding the display coordinates of each point in turn.

Turning to the problem of the horizon and referencing Figure 12 below the following computations are presented.

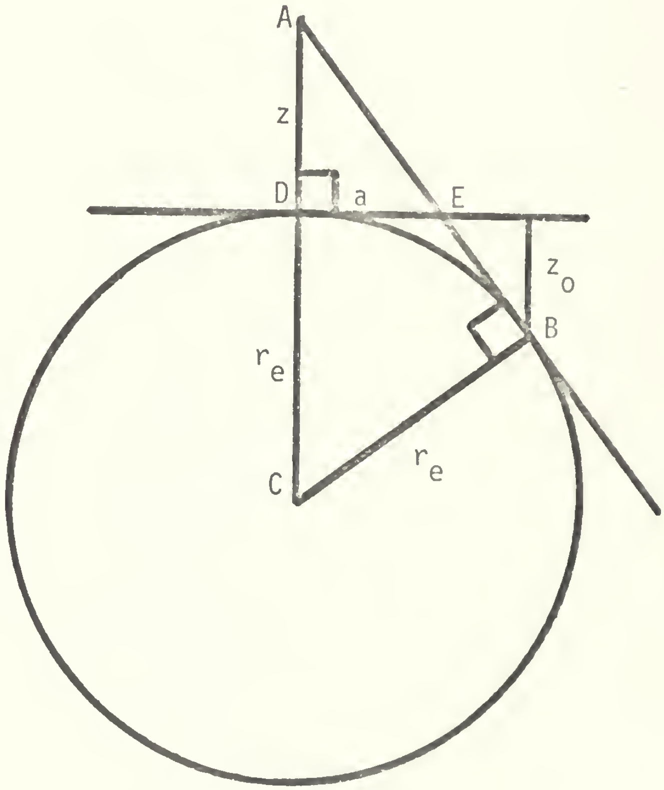


Figure 12. Horizon and Earth.

For an aircraft at point A with altitude z above the earth with radius r_e, the true horizon is at point B. This is depressed a distance z_o from the plane DE which is tangent to the earth at point D. However,

a pseudo horizon exists at point E which always has a z coordinate of zero and visually coincides with the true horizon but has the advantage of being quicker to draw.

From Figure 12, since triangle ADE and ABC are similar this yields:

$$\frac{DE}{AD} = \frac{a}{z} = \frac{BC}{AB} = \frac{r_e}{AB}$$

$$a = \frac{R_e(z)}{AB}$$

$$(z + r_e)^2 = AB^2 + r_e^{\ 2}$$

$$AB = (z^2 + 2(r_e)z)^{\frac{1}{2}}$$

$$a = \frac{r_e(z)^{\frac{1}{2}}}{(z - 2r_e)^{\frac{1}{2}}}$$

assuming $2r_e$ to be very much greater than z yields:

$$a = \frac{r_e(z)^{\frac{1}{2}}}{(2r_e)^{\frac{1}{2}}} = K(z)^{\frac{1}{2}} \quad \text{where } K = \frac{(41.8)^{\frac{1}{2}}}{2} \times 10^3$$

The depression angle of the horizon is:

$$\text{dep} = 90° - \tan^{-1}(a/z) = 90° - \tan^{-1}(K(z)^{\frac{1}{2}}/z)$$

Referring to Figure 13, which is a view of the window and horizon, the object is to calculate YMID, the y intercept of the horizon. The distance PITCH can be calculated knowing the pitch angle and the field view.

$$\text{PITCH} = \theta/\text{Field of View}$$

TPITCH is PITCH minus the depression angle DEPA. Simple trig yields $\cos\phi$ = TPITCH/YMID, where ϕ is the roll angle of the aircraft.

$$\text{YMID} = \text{TPITCH}/\cos\phi$$

Knowing YMID and the roll angle the horizon can then be constructed. Upon the completion of the runway and the horizon, the lines are placed through a software window algorithm that will cause only the lines within the window/field of view to be displayed. This computation is done for every iteration of the problem solution.

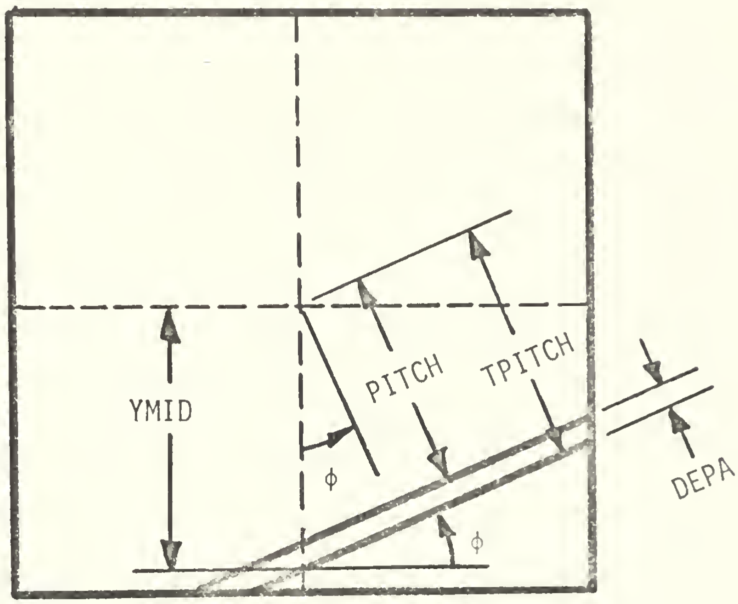


Figure 13. Calculating Horizon Intercept.

VI. THE PROGRAM

As stated in Section III, a logical division of tasks exist. To integrate the derivatives of the twelve state variables by digital algorithms takes too much computational time, therefore the logical thing to do was to D/A these variables and integrate them on a real-time basis using the analog computer. The results are then A/D'd back to the digital computer for calculation of the derivatives. This forms the computational loop.

When a real-time simulation is undertaken the time involved for the solution of the problem must be a minimum. Great pains were taken to insure that this was indeed done. The following is a tabulation of the significant time-saving steps that were involved:

1. Resolution of the angles in the digital computer using a sine table lookup.
2. Fast linear interpolation used in both the sine table lookup and the aerodynamic coefficient lookup.
3. Preprocessing of the aerodynamic data to yield usable aerodynamic coefficients.
4. General and liberal use of program constants to combine two or more arithmetic operations.
5. Use of the SQRT function vice the exponential function.
6. Multiple assignment.
7. Rewriting by the Laboratory staff of the A/D - D/a routine resulting in the SUBROUTINE ADDA.
8. Rewriting of the digital processor control program GATED to yield a faster version GATD1.

9. The use of equivalencing scalars to vector elements to reduce the indexing time within the digital computer.

10. Judicious programming and a dedicated cleaning up process of the generated code for the computational loop.

The total time for the computational loop using the above procedures was cut from an original 190 milliseconds to 55 milliseconds. This gives an approximate solution update rate and graphic frame rate of 18 samples or frames per second.

The simulator was finally flown but the dynamic response was not quite as expected. The aircraft seemed to be unstable in the Dutch Roll mode, so a yaw damper was constructed. This helped, but at times the aircraft was still unstable. Investigation into dynamic error analysis [Ref. 5] demonstrated that the computational loop time delay was causing a degradation in the damping ratio. The lowest damping ratio was in the Dutch Roll mode, hence the appearance of the instability there. The solution was to predict ahead a value to be used by the program using the known derivatives. When this prediction and update was incorporated, all instabilities were corrected.

Engine dynamic response was added in an effort to make the throttle response realistic [Ref. 6]. Also, in an attempt to increase the number of cues available to the pilot, variable frequency noise was generated in proportion to the power applied. When weighed against the results achieved, it was decided to discard the noise generator in favor of the simplicity of setup and operation.

The digital program in its entirety can be found in Appendix A, while the analog diagram can be found in Appendix B. In an effort to make the program more readable, Appendix C contains descriptors of all

the program variables used, and Appendix D contains a program flow diagram. Sample output of the program can be found in Appendix G.

VII. CONCLUSIONS

Dynamic validation of the simulator was done by comparing the various modes of response. The tabulation below shows that in fact the dynamic response of the simulator is excellent when compared with the actual aircraft, in this case the A-7.

		Simulator	Aircraft
1.	Dutch Roll Natural Frequency	.25 cps	.25 cps
2.	Short Period	2.0 sec	2.3 sec
3.	Phygoid Period	37 sec	38 sec
4.	Roll Mode	Heavily damped in both cases	
5.	Spiral Divergence Time Constant	29 sec	25-35 sec

The simulator has now met the self-imposed requirements set forth in the Introduction. Briefly reviewing the points in the Introduction:

1. Multi-task simulator - Currently three follow-on studies are being conducted using the simulator. These include a spin simulation, investigation into stall dynamics and a study involved with a LSO work station.
2. Ability to change the aircraft being simulated - Demonstrations have been conducted with the "standard" Navy runway and the carrier runway dimensions as well as linearized and non-linearized aerodynamic data. Time involved to change, in each case, was approximately one minute.
3. The use of interactive graphics for the display - Very good results were achieved using the inside-out display. Results show that there is a learning curve as with any simulator but

sufficient visual cues are provided to enable consistent landings by experienced pilots.

4. Simplicity of setup and operation - The number of dials or buttons have been kept to a minimum; as a result the system can be up and operating within five minutes. As for the operation, the simulator has been flown by all manner of people with little or no explanation needed.

Possible areas of follow-on study might include the following:

1. The study of Heads Up Displays (HUD's), since only the graphic presentation need be changed.

2. Autopilot/Gust Alleviators/Stability Augmentor systems that can be modeled on an analog board can be incorporated, as approximately one-half the board is left unused for this purpose.

3. Force-stick analyzation with a realistic tracking problem.

4. Re-design of the Optical Landing System to reduce the false motion cues that currently exist in the present system.

APPENDIX A - THE DIGITAL PROGRAM

This appendix includes listings of the main program, written in FORTRAN, and the SUBROUTINE ADDA, the A/D - D/A subprogram. The subroutine is written in METASYMBOL, the assembly language for the XDS - 9300 and was prepared gy the computer laboratory staff.

```
**************************************************************************
*                                                                        *
*                CARRIER APPRØACH LANDING SIMULATØR                      *
*                                                                        *
*                                BY                                      *
*                         LCDR J.H. KAHRS                                *
*                               AND                                      *
*                         LTJG M.H. REDLIN                               *
*                                                                        *
**************************************************************************
      DIMENSIØN A(5),CA(5),SA(5),ADØTB(1),C(24),CØEFA(5:24,15),
     XCØEFAB(4,15,9),SDØT(3),TRIG(271),PØT(0:50),ADØTN(5),AD(20),
     XAA(12),SFA(5),ITEX91(4),ITEX92(5),ITEX93(4),
     XITEX94(7),ITEX95(5),ITEX96(4),ITEX97(7),ITEX98(6),ITEX72(4),
     XITEX71(8),ITEX70(2),ITEX99(8),ITEX73(6),ITEX74(2),ITEX75(2),
     XITEX76(3),ITEX77(3),ITEX78(3),ITDIR(20),ITEX1(5),
     XITEX2(5),ITEX3(2),ITEX4(1),ITEX5(4),ITEX6(1),ITEX7(5),ITEX8(5),
     XITEX9(7),ITEX10(3),ITEX11(4),ITEX12(12),ITEX13(8),ITEX14(12),
     XITEX15(12),ITEX16(4),ITEX17(11),ITEX18(4),ITEX19(12),ITEX20(6),
     XH1(4,4),H2(4,4),H3(4,4),Z(4,4),H(4,4),P1(1,4),P2(1,4),
     XP3(1,4),P4(1,4),P5(1,4),P6(1,4),IDIR(3),ISO(52),XSTART(8),
     XYSTART(8),XEND(8),YEND(8),IØØN(5),IFAST(3),ISLØ(3),IDE(30),
     XADØTB(5),ITEX30(8),ITEX31(7),ITEX32(11),ITEX33(7),ITEX34(12),
     XITEX35(11),ITEX36(3),ITEX37(12),ITEX38(11),ITEX39(11),
     XITEX40(2),ITEX41(7),ITEX42(5),NULL(2),ITEX44(6),
     XITEX43(8),ITEX45(6),ITEX46(7),ITEX47(6),ITEX48(4),DEGA(15),
     X DEGB(9),KK(8),KPØT(40)
      EQUIVALENCE (H(1,2),HH12),(H(1,3),HH13),(H(1,4),HH14),
     X(H(2,2),HH22),(H(2,3),HH23),(H(2,4),HH24),(SFA(5),SF12),
     X(H(3,2),HH32),(H(3,3),HH33),(H(3,4),HH34),(SFA(4),SF11),
     X(H(4,2),HH42),(H(4,3),HH43),(H(4,4),HH44),(SFA(3),SF10),
     X(P1(1,1),PP11),(P1(1,2),PP12),(P1(1,3),PP13),(P1(1,4),PP14),
     X(P2(1,1),PP21),(P2(1,2),PP22),(P2(1,3),PP23),(P2(1,4),PP24),
     X(P3(1,1),PP31),(P3(1,2),PP32),(P3(1,3),PP33),(P3(1,4),PP34),
     X(P4(1,1),PP41),(P4(1,2),PP42),(P4(1,3),PP43),(P4(1,4),PP44),
```

```
     X(P5(1,1),PP51),(P5(1,2),PP52),(P5(1,3),PP53),(P5(1,4),PP54),
     X(P6(1,1),PP61),(P6(1,2),PP62),(P6(1,3),PP63),(P6(1,4),PP64),
     X(CA(1),CCA1),(CA(2),CCA2),(SA(1),SSA1),(SA(2),SSA2),
     X(CA(3),CCA3),(CA(4),CCA4),(CA(5),CCA5),(SA(3),SSA3),
     X(SA(4),SSA4),(SA(5),SSA5),(AD(7),QS,Q),(H1(4,1),SX),(H1(4,2),SY),
     X(H1(4,3),SZ),(AD(1),A(1)),(AD(2),A(2)),(AD(3),A(3)),(AD(4),A(4)),
     X(AD(5),A(5)),(AD(6),P),(AD(8),R),(AD(9),TM),(AD(10),DIT)
     X,(AD(11),DA),(AD(12),DR),(AD(13),V),(AD(14),QUE),(AD(15),SXN),
     X(AD(16),SYN),(AD(17),SZN),(AA(1),VDØT),(AA(2),ADØTN(1)),
     X(AA(3),ADØTN(2)),(AA(4),ADØTN(3)),(AA(5),ADØTN(4)),
     X(AA(6),ADØTN(5)),(AA(7),ALI),(AA(8),SDØT(1)),(AA(9),SDØT(2)),
     X (AA(10),SDØT(3)),(AA(11),AMI),(AA(12),ANI),(SFA(1),SF8),
     X(SFA(2),SF9),(AD(18),PDØTN),(AD(19),QDØTN),(AD(20),RDØTN)
      DATA AD/12*0.0,.6,.36,6*0.0/,NDA/12/,NAD/20/,G/32.2/,H1(1,2),
     XH1(1,3),H1(1,4),H1(2,1),H1(2,3),H1(2,4),H1(3,1),H1(3,2),H1(3,4),
     XH2(2,4),H2(3,4),H2(4,1),H2(4,2),H2(4,3),H3(3,2),H3(2,3),Z9,Y8,
     XH3(2,4),H3(3,4),H2(1,4)/21*0.0/,H1(1,1),H1(2,2),H1(3,3),H1(4,4),
     XH2(4,4),H3(2,2),H3(3,3)/7*1.0/,SFACTR/.5/,F/1.5/,ADØTØ/5*0.0/,
     XVDØTØ/0.0/,DEGB/-40.,-30.,-20.,-10.,0.0,10.,20.,30.,40./,
     XDEGA/-25.,-20.,-15.,-10.,-5.,0.0,5.,10.,15.,20.,25.,30.,35.,
     X40.,45./,KK/5,9,10,14,15,19,20,24/,KPØT/0,24,1,25,2,26,3,27,4,30,
     X5,31,6,32,7,33,10,34,11,35,12,36,13,37,14,40,15,41,16,42,17,43,
     X20,44,21,45,22,46,23,50/
C***********************************************************************
C*                                                                     *
C*                        FØRMAT STATEMENTS                            *
C*                                                                     *
C***********************************************************************
   51 FØRMAT(3F10.0)
  100 FØRMAT(I1)
  102 FØRMAT(4F10.0)
  103 FØRMAT(I2,2X,I1,5X,7F10.7/8F10.7)
  104 FØRMAT(I2,8X,7F10.7/8F10.7)
  105 FØRMAT('0',I2,2X,I1,5X,7(F10.7,2X)/' ',8(F10.7,2X))
  106 FØRMAT('0',I2,8X,7(F10.7,2X)/' ',8(F10.7,2X))
```

```
107 FØRMAT('1',' ')
108 FØRMAT(8F10.0)
110 FØRMAT(6F10.2)
111 FØRMAT(8F10.2/8F10.2/3F10.2)
120 FØRMAT('0',20X,'A000 INDICATES -PDØT/',F5.2,4X,
   X'A001 INDICATES +P/',F5.2,7X,
   X'A002 INDICATES -QDØT/',F5.2,//,21X,
   X'A003 INDICATES +Q/',F5.2,7X,
   X'A006 INDICATES -RDØT/',F5.2,4X,
   X'A007 INDICATES +R/',F5.2,//,21X,
   X'A015 INDICATES +T/RMASS/',F3.0,3X,
   X'A017 INDICATES -SX/',F6.0,5X,
   X'A051 INDICATES -SY/',F6.0,//,21X,
   X'A023 INDICATES -SZ/',F6.0,5X,
   X'A024 INDICATES DIT/',F3.0,8X,
   X'A025 INDICATES THETA/',F3.0,//,21X,
   X'A026 INDICATES DA/',F3.0,9X,
   X'AC31 INDICATES PETA/',F3.0,7X,
   X'AC33 INDICATES PHI/',F3.0,//,21X,
   X'AC34 INDICATES QUE/',F6.2,5X,
   X'A035 INDICATES PSI/',F3.0,8X,
   X'A036 INDICATES VEL/',F4.0,//,21X,
   X'AC41 INDICATES DR/',F3.0,9X,
   X'AC45 INDICATES ALPHA/',F3.0,//)
121 FØRMAT('0',20X,'T420 INDICATES VDØT/',F3.0,7X,
   X'T421 INDICATES -ALPHADØT/',F3.1,2X,
   X'T422 INDICATES -BETADØT/',F3.1,//,21X,
   X'T423 INDICATES -PSIDØT/',F3.1,4X,
   X'T424 INDICATES -THETADØT/',F3.1,2X,
   X'T425 INDICATES -PHIDØT/',F3.1,//,21X,
   X'T426 INDICATES ALI/',F4.2,7X,
   X'T427 INDICATES SXDØT/',F4.0,5X,
   X'T430 INDICATES SYDØT/',F4.0,//,21X,
   X'T431 INDICATES SZDØT/',F4.0,5X,
   X'T432 INDICATES AMI/',F4.2,7X,
```

```
   X'T433 INDICATES ANI/',F4.2)
122 FORMAT(' ',20X,'THE OUTPUTS OF THE AMPLIFIERS ARE REPRESENTATIVE O
   XF THE FOLLOWING SCALED VARIABLES:')
123 FORMAT(' ',20X,'THE D/A TRUNKS REPRESENT THE FOLLOWING SCALED VARI
   XABLES:')
130 FORMAT('THE FOLLOWING PROGRAM OPTIONS    ')
131 FORMAT('ARE OFFERED AT THIS TIME :  ')
132 FORMAT('1. TO STOP PROGRAM - TYPE A 1 FOLLOWED BY A ')
133 FORMAT('DECIMAL POINT AND A RETURN. ')
134 FORMAT('2. TO FLY AGAIN WITH SAME PROGRAM PARAMETERS -  ')
135 FORMAT('TYPE A 2 FOLLOWED BY A DECIMAL POINT AND     ')
136 FORMAT('A RETURN.    ')
137 FORMAT('3. TO CHANGE ANY PROGRAM PARAMETER - LOAD AND    ')
138 FORMAT('READY CARD READER WITH COMPLETE DATA DECK - ')
139 FORMAT('TYPE A 3 FOLLOWED BY A DECIMAL POINT AND A  ')
140 FORMAT('RETURN. ')
141 FORMAT('TYPE YOUR SELECTION HERE     ')
142 FORMAT('USE A DECIMAL POINT ')
143 FORMAT('TO FLY AGAIN PUNCH THE BUTTON    ')
144 FORMAT('INPUT ERROR TRY AGAIN    ')
145 FORMAT('ON THE CONTROL STICK.    ')
146 FORMAT('TO RECEIVE PROGRAM OPTIONS  ')
147 FORMAT('PUNCH THE BUTTON ON THE ')
148 FORMAT('THROTTLE PLATE. ')
301 FORMAT('CARRIER APPROACH     ')
302 FORMAT('LANDING SIMULATOR    ')
303 FORMAT('(CALS)  ')
304 FORMAT('BY  ')
305 FORMAT('LCDR J.H. KAHRS ')
306 FORMAT('AND ')
307 FORMAT('LTJG M.H. REDLIN     ')
308 FORMAT('ASST PROF AERO ENG  ')
309 FORMAT('NAVAL POSTGRADUATE SCHOOL    ')
310 FORMAT('MARCH 1972  ')
311 FORMAT('INSTRUCTIONS     ')
```

```
312 FØRMAT('PLACE CØNTRØLS AT THE NEUTRAL PØSITIØN AND SET  ')
313 FØRMAT('THE THRØTTLE AT THE WHITE MARK. ')
314 FØRMAT('WHEN THE INSTRUCTIØNS ARE UNDERSTØØD, PUNCH THE ')
315 FØRMAT('BUTTØN ØN THE THRØTTLE PLATE FØR THE GRAPHIC    ')
316 FØRMAT('PRESENTATIØN.    ')
317 FØRMAT('WHEN READY TØ FLY PUNCH THE BUTTØN ØN THE    ')
318 FØRMAT('CØNTRØL STICK.  ')
319 FØRMAT('TØ ABØRT A RUN WHILE FLYING, PUNCH THE BUTTØN    ')
320 FØRMAT('ØN THE THRØTTLE PLATE.  ')
700 FØRMAT('0',50X,'CØEFFICIENT NUMBER ',I1,//)
701 FØRMAT(' ',11X,'BETA',3X,9(F5.1,6X))
702 FØRMAT(' ',10X,'ALPHA',/)
703 FØRMAT('0',10X,F5.1,9(1X,F10.7))
704 FØRMAT(' ',32X,5('CØEFFICIENT',2X))
705 FØRMAT(' ',34X,5('NUMBER',7X))
706 FØRMAT(' ',25X,'ALPHA',6X,5(I2,11X),/)
707 FØRMAT('0',25X,F5.1,2X,5(F10.7,3X))
760 FØRMAT(' ',11X,'ØRIGINAL CØEF ARRAY')
761 FØRMAT(' ',11X,'USABLE CØEF ARRAY')
762 FØRMAT(' ',25X,'ØRIGINAL CØEF ARRAYS',/)
763 FØRMAT(' ',25X,'USABLE CØEF ARRAYS',/)
780 FØRMAT(' ',//////////////)
781 FØRMAT(' ',40X,'SF1  = ',F10.3,20X,'SF30 = ',F10.3,//,
   X41X,'SF2  = ',F10.3,20X,'SF31 = ',F10.3,//,
   X41X,'SF3  = ',F10.3,20X,'SF32 = ',F10.3,//,
   X41X,'SF4  = ',F10.3,20X,'SF33 = ',F10.3,//,
   X41X,'SF5  = ',F10.3,20X,'SF34 = ',F10.3,//,
   X41X,'SF6  = ',F10.3,20X,'SF35 = ',F10.3,//,
   X41X,'SF7  = ',F10.3,20X,'SF36 = ',F10.3,//,
   X41X,'SF8  = ',F10.3,20X,'SF37 = ',F10.3,//,
   X41X,'SF9  = ',F10.3,20X,'SF38 = ',F10.3,//,
   X41X,'SF10 = ',F10.3,20X,'SF39 = ',F10.3,//,
   X41X,'SF11 = ',F10.3,20X,'SF40 = ',F10.3,//,
   X41X,'SF12 = ',F10.3,//,
   X41X,'SF13 = ',F10.3,20X,'SX0  = ',F10.3,//,
```

```
    X41X,'SF14 = ',F10.3,20X,'SZO  = ',F10.3,//,
    X41X,'SF15 = ',F10.3,20X,'VO   = ',F10.3,//,
    X41X,'SF16 = ',F10.3,20X,'A10  = ',F10.3,//,
    X41X,'SF17 = ',F10.3,20X,'DITO = ',F10.3,//,
    X41X,'SF18 = ',F10.3,20X,'RHO  = ',F10.5,//,
    X41X,'SF19 = ',F10.3,20X,'WIND = ',F10.3,//,
    X41X,'SF20 = ',F10.3,//,
    X41X,'SF21 = ',F10.3,20X,'W    = ',F10.3,//,
    X41X,'SF22 = ',F10.3,20X,'B    = ',F10.3,//,
    X41X,'SF23 = ',F10.3,20X,'CB   = ',F10.3,//,
    X41X,'SF24 = ',F10.3,20X,'S    = ',F10.3,//,
    X41X,'SF25 = ',F10.3,20X,'RIXX = ',F10.3,//,
    X41X,'SF26 = ',F10.3,20X,'RIYY = ',F10.3,//,
    X41X,'SF27 = ',F10.3,20X,'RIZZ = ',F10.3,//,
    X41X,'SF28 = ',F10.3,20X,'RIXZ = ',F10.3,//,
    X41X,'SF29 = ',F10.3,20X,'T    = ',F10.3,//,
    X41X,'ABALDG = ',F8.3,20X,'SZF  = ',F10.3)
790 FORMAT(' ',58X,'RUNWAY CONSTANTS')
791 FORMAT('0',50X,'POINT',7X,'X',8X,'Y',8X,'Z',///,
    X53X,'1',4X,3(F7.1,2X),///,53X,'2',4X,3(F7.1,2X),///,
    X53X,'3',4X,3(F7.1,2X),///,53X,'4',4X,3(F7.1,2X),///,
    X53X,'5',4X,3(F7.1,2X),///,53X,'6',4X,3(F7.1,2X),///)
792 FORMAT(' ',58X,'XMIR = ',F9.3,///,59X,'HMIR = ',F9.3,///,
    X59X,'GSB  = ',F9.3,///,59X,'RAMP = ',F9.3,///,
    X59X,'W1   = ',F9.3,///,59X,'W2   = ',F9.3,///,
    X59X,'W3   = ',F9.3,///,59X,'W4   = ',F9.3)
901 FORMAT('LANDING RESULTS ')
902 FORMAT('YOU HAVE CRASHED    ')
903 FORMAT('BOLTER  BOLTER  ')
904 FORMAT('YOU  HAVE MISSED THE SHIP     ')
905 FORMAT('ARRESTED LANDING    ')
906 FORMAT('WIRE NUMBER ',I1,'   ')
907 FORMAT('SINK RATE = ',F7.2,' FT/SEC  ')
908 FORMAT('CAUTION - BLOWN TIRE     ')
909 FORMAT(F5.1,' FEET LEFT OF CENTERLINE    ')
```

```
 970 FØRMAT('LINE-UP ')
 971 FØRMAT(F5.1,' FEET RIGHT ØF CENTERLINE  ')
 972 FØRMAT('ØN CENTERLINE    ')
 973 FØRMAT('AIRSPEED AT TØUCHDØWN    ')
 974 FØRMAT('FAST     ')
 975 FØRMAT('SLØW     ')
 976 FØRMAT('ØN SPEED      ')
 977 FØRMAT('LITTLE FAST ')
 978 FØRMAT('LITTLE SLØW ')
8001 FØRMAT(' ',40X,'PØT(',I1,')  = ',F6.5,20X,'PØT(',I2,') = ',F6.5)
8002 FØRMAT(' ',40X,'PØT(',I2,') = ',F6.5,20X,'PØT(',I2,') = ',F6.5)
9000 FØRMAT(' ',40X,'PØT SETTINGS',//)
************************************************************************
*                                                                      *
*                              THE TITLE                               *
*                                                                      *
************************************************************************
8003 ØUTPUT(101)'INPUT AGT NUMBER'
     READ(101,100)IDEV
     IF((IDEV.NE.1).AND.(IDEV.NE.2)) GØ TØ 8003
     CALL DGINIT(IDEV,IDIR,3,IER)
     CALL DTINIT(IDEV,ITDIR,20,IER)
     ENCØDE(20,301,ITEX1)
     ENCØDE(20,302,ITEX2)
     ENCØDE(8,303,ITEX3)
     ENCØDE(4,304,ITEX4)
     ENCØDE(16,305,ITEX5)
     ENCØDE(4,306,ITEX6)
     ENCØDE(20,307,ITEX7)
     ENCØDE(20,308,ITEX8)
     ENCØDE(28,309,ITEX9)
     ENCØDE(16,310,ITEX10)
     CALL TEXTØ(IDEV,ITEX1,5,2,24,3,3,IER)
     CALL TEXTØ(IDEV,ITEX2,5,7,22,3,3,IER)
     CALL TEXTØ(IDEV,ITEX3,2,10,39,3,3,IER)
```

```
      CALL TEXTØ(IDEV,ITEX4,1,16,46,2,3,IER)
      CALL TEXTØ(IDEV,ITEX5,4,19,25,3,3,IER)
      CALL TEXTØ(IDEV,ITEX6,1,22,45,2,3,IER)
      CALL TEXTØ(IDEV,ITEX7,5,25,24,3,3,IER)
      CALL TEXTØ(IDEV,ITEX8,5,28,30,2,3,IER)
      CALL TEXTØ(IDEV,ITEX9,7,34,23,2,3,IER)
      CALL TEXTØ(IDEV,ITEX10,3,37,38,2,3,IER)
**************************************************************************
*                                                                        *
*                          READ RUNWAY DATA                              *
*                                                                        *
**************************************************************************
      READ(5,102)(P1(1,J),J=1,4)
      READ(5,102)(P2(1,J),J=1,4)
      READ(5,102)(P3(1,J),J=1,4)
      READ(5,102)(P4(1,J),J=1,4)
      READ(5,102)(P5(1,J),J=1,4)
      READ(5,102)(P6(1,J),J=1,4)
      READ(5,51) GSØ,XMIR,WIND
**************************************************************************
*                                                                        *
*                    ESTABLISH PRØGRAM CØNSTANTS                         *
*                                                                        *
**************************************************************************
      CØN1=57.29577
      CØN2=.2/.75
      CØN3=SQRT(41.8)*1000.0/2.0
      CØN4=SIN(30.0/CØN1)
      CØN5=CØS(30.0/CØN1)
      CØN6=CØN3/CØN5
      IDE(1)=IHEAD(0,10)
      HMIR=115.0*SIN(GSØ/CØN1)/CØS(GSØ/CØN1)
      H3(1,2)=-YØ/F
      H3(1,3)=-ZØ/F
      H3(1,4)=-SFACTR/F
```

```
      H3(4,2)=YØ
      H3(4,3)=ZØ
      H3(4,4)=SFACTR
      DEGMAX=CØN1*ATAN(ABS(SFACTR/F))
      RAMP=PP41
      TAU=.056*1.5
C**************************************************************************
C*                                                                        *
C*                      BUILD FIXED PØRTIØN ØF GRAPHICS                   *
C*                                                                        *
C**************************************************************************
      ISQ(1)=IHEAD(0,10)
      ISQ(2)=IPACK(1.0,1.0,0)
      ISQ(3)=IPACK(1.0,-1.0,1)
      ISQ(4)=IPACK(-1.0,-1.0,1)
      ISQ(5)=IPACK(-1.0,1.0,1)
      ISQ(6)=IPACK(1.0,1.0,1)
      ISQ(7)=IPACK(-1.0,1.0,0)
      ISQ(8)=IPACK(-1.0,1.04,1)
      ISQ(9)=IPACK(-0.8,1.04,1)
      ISQ(10)=IPACK(-0.8,1.0,1)
      ISQ(11)=IPACK(-1.2,1.0,0)
      ISQ(12)=IPACK(-1.4,1.0,1)
      ISQ(13)=IPACK(-1.4,1.04,1)
      ISQ(14)=IPACK(-1.2,1.04,1)
      ISQ(15)=IPACK(-1.2,1.0,1)
      ISQ(16)=IPACK(-1.2,0.0,0)
      ISQ(17)=IPACK(-1.0,0.0,1)
      ISQ(18)=IPACK(1.0,0.0,0)
      ISQ(19)=IPACK(1.2,0.0,1)
      ISQ(20)=IPACK(-1.1,(10.0/18.5),0)
      ISQ(21)=IPACK(-1.0,(10.0/18.5),1)
      ISQ(22)=IPACK(1.0,(10.0/18.5),0)
      ISQ(23)=IPACK(1.1,(10.0/18.5),1)
      ISQ(24)=IPACK(-1.1,(-10.0/18.5),0)
```

```
ISQ(25)=IPACK(-1.0,(-10.0/18.5),1)
ISQ(26)=IPACK(1.0,(-10.0/18.5),0)
ISQ(27)=IPACK(1.1,(-10.0/18.5),1)
ISQ(28)=IPACK(-1.12,.52,0)
ISQ(29)=IPACK(-1.12,.56,1)
ISQ(30)=IPACK(-1.16,.56,1)
ISQ(31)=IPACK(-1.16,.52,1)
ISQ(32)=IPACK(-1.12,.52,1)
ISQ(33)=IPACK(-1.2,.52,0)
ISQ(34)=IPACK(-1.2,.56,1)
ISQ(35)=IPACK(-1.25,-.52,0)
ISQ(36)=IPACK(-1.25,-.56,1)
ISQ(37)=IPACK(-1.24,.54,0)
ISQ(38)=IPACK(-1.26,.54,1)
ISQ(39)=IPACK(-1.24,-.04,0)
ISQ(40)=IPACK(-1.24,.04,1)
ISQ(41)=IPACK(-1.32,.04,1)
ISQ(42)=IPACK(-1.32,-.04,1)
ISQ(43)=IPACK(-1.24,-.04,1)
ISQ(44)=IPACK(-1.12,-.52,0)
ISQ(45)=IPACK(-1.12,-.56,1)
ISQ(46)=IPACK(-1.16,-.56,1)
ISQ(47)=IPACK(-1.16,-.52,1)
ISQ(48)=IPACK(-1.12,-.52,1)
ISQ(49)=IPACK(-1.2,-.52,0)
ISQ(50)=IPACK(-1.2,-.56,1)
ISQ(51)=IPACK(-1.24,-.54,0)
ISQ(52)=IPACK(-1.26,-.54,1)
IFAST(1)=IPACK(1.04,0.8,0)
IFAST(2)=IPACK(1.12,0.88,1)
IFAST(3)=IPACK(1.2,0.8,1)
IDRN(1)=IPACK(1.08,0.96,0)
IDRN(2)=IPACK(1.08,1.04,1)
IDRN(3)=IPACK(1.16,1.04,1)
IDRN(4)=IPACK(1.16,0.96,1)
```

```
      IDØN(5)=IPACK(1.08,0.96,1)
      ISLØ(1)=IPACK(1.04,1.2,0)
      ISLØ(2)=IPACK(1.12,1.12,1)
      ISLØ(3)=IPACK(1.2,1.2,1)
***********************************************************************
*                                                                     *
*              READ SCALE FACTØRS AND FIXED AIRCRAFT DATA             *
*                                                                     *
***********************************************************************
      READ(5,111) SF1,SF2,SF3,SF4,SF5,SF6,SF8,SF9,SF10,SF11,SF12,SF13,
     1SF14,SF15,SF16,SF17,SF18,SF19,SF30
      READ(5,110) SX0,SZ0,V0,A10,DIT0,RHØ
      READ(5,108)W,B,CB,S,RIXX,RIYY,RIZZ,RIXZ
      READ(5,51)T,AØALDG,SZF
      AØAF=AØALDG-2.0
      AØALF=AØALDG-1.0
      AØALS=AØALDG+1.0
      AØAS=AØALDG+2.0
      RMASS=W/G
      ISF7=T/(RMASS*10.)+1.0
      SF7=ISF7*10
      SF20=SF1*SF1/(2.*SF19)
      SF21=SF6/SF4
      SF22=SF1/SF4
      SF23=SF1/SF5
      SF24=SF1/SF6
      SF25=SF4/SF5
      SF26=SF5/SF6
      SF27=SF4*SF4
      SF28=SF5*SF5
      SF29=SF6*SF6
      SF31=SF7/(SF1*SF5)
      SF32=SF7/(SF1*SF6)
      SF33=SF1/SF2
      SF34=SF1/SF3
```

```
      SF35=C0N1*SF5/SF8
      SF36=C0N1*SF6/SF9
      SF37=C0N1*SF6/SF10
      SF38=C0N1*SF5/SF11
      SF39=C0N1*SF4/SF12
      SF40=SF7/SF1
      W5=(XMIR+115.0)+SZF*C0S(GS9/C0N1)/SIN(GS9/C0N1)
      W2=W5+15.0
      W1=W2+33.0
      W3=W2-33.0
      W4=W3-33.0
      IF(TEST(7).GT.0) G0 T0 10
      WRITE(6,107)
      WRITE(6,780)
      WRITE(6,790)
      WRITE(6,791)PP11,PP12,PP13,PP21,PP22,PP23,PP31,PP32,PP33,PP41,
     XPP42,PP43,PP51,PP52,PP53,PP61,PP62,PP63
      WRITE(6,792)XMIR,HMIR,GS9,RAMP,W1,W2,W3,W4
      WRITE(6,107)
      WRITE(6,780)
      WRITE(6,781)SF1,SF30,SF2,SF31,SF3,SF32,SF4,SF33,SF5,SF34,SF6,SF35,
     XSF7,SF36,SF8,SF37,SF9,SF38,SF10,SF39,SF11,SF40,SF12,SF13,SX0,
     XSF14,S70,SF15,V0,SF16,A10,SF17,DIT0,SF18,RH9,SF19,WIND,SF20,SF21,
     XW,SF22,B,SF23,CB,SF24,S,SF25,RIXX,SF26,RIYY,SF27,RIZZ,SF28,
     XRIXZ,SF29,T,A0ALDG,SZF
   10 GEE=G/SF7
      B2=B/2.0
      CB2=CB/2.0
*****************************************************************
*                                                               *
*                        BUILD TRIG TABLE                       *
*                                                               *
*****************************************************************
      D0 230 I=1,271
      TRIG(I)=SIN((I-91.0)/C0N1)
```

```
  230 CØNTINUE
************************************************************************
*                                                                      *
*                      READ AIRCRAFT CØEFFICIENTS                      *
*                                                                      *
************************************************************************
      DØ 200 J=1,36
      READ(5,103)I,IB,(CØEFAB(I,IA,IB),IA=1,15)
  200 CØNTINUE
      DØ 220 J=1,20
      READ(5,104) I,(CØEFA(I,IA),IA=1,15)
  220 CØNTINUE
      IF (TEST(7).GT.0) GØ TØ 721
      WRITE(6,107)
      WRITE(6,780)
      DØ 720 I=1,4
      WRITE(6,760)
      WRITE(6,700)I
      WRITE(6,701)(DEGB(J),J=1,9)
      WRITE(6,702)
      DØ 719 IA=1,15
      WRITE(6,703)DEGA(IA),(CØEFAB(I,IA,IB),IB=1,9)
  719 CØNTINUE
      WRITE(6,107)
      WRITE(6,780)
  720 CØNTINUE
      DØ 721 I=1,7,2
      IPLS=I+1
      WRITE(6,762)
      WRITE(6,704)
      WRITE(6,705)
      WRITE(6,706)(J,J=KK(I),KK(IPLS))
      DØ 722 IA=1,15
      WRITE(6,707) DEGA(IA),(CØEFA(J,IA),J=KK(I),KK(IPLS))
  722 CØNTINUE
```

```
      WRITE(6,107)
      WRITE(6,780)
  721 CONTINUE
***************************************************************************
*                                                                         *
*                    COMPUTE USABLE AIRCRAFT COEFFICIENTS                 *
*                                                                         *
***************************************************************************
      DO 5001 IB=1,9
      DO 5002 IA=1,15
      COEFAB(1,IA,IB)=S*B*COEFAB(1,IA,IB)/RIXX*SF20/SF27
      COEFAB(2,IA,IB)=S*CB*COEFAB(2,IA,IB)/RIYY*SF20/SF28
      COEFAB(3,IA,IB)=S*B*COEFAB(3,IA,IB)/RIZZ*SF20/SF29
      COEFAB(4,IA,IB)=S*COEFAB(4,IA,IB)/RMASS*SF20/SF7
 5002 CONTINUE
 5001 CONTINUE
      DO 5003 IA=1,15
      COEFA(5,IA)=-S*COEFA(5,IA)/RMASS*SF20/SF7
      COEFA(6,IA)=-S*COEFA(6,IA)/RMASS*SF20/SF7
      COEFA(7,IA)=-S*COEFA(7,IA)/RMASS*SF16*SF20/SF7
      COEFA(8,IA)=S*CB*COEFA(8,IA)/RIYY*SF16*SF20/SF28
      COEFA(9,IA)=S*COEFA(9,IA)/RMASS*SF18*SF20/SF7
      COEFA(10,IA)=S*B*COEFA(10,IA)/RIXX*SF18*SF20/SF27
      COEFA(11,IA)=S*B*COEFA(11,IA)/RIZZ*SF18*SF20/SF29
      COEFA(12,IA)=S*COEFA(12,IA)/RMASS*SF17*SF20/SF7
      COEFA(13,IA)=S*B*COEFA(13,IA)/RIXX*SF17*SF20/SF27
      COEFA(14,IA)=S*B*COEFA(14,IA)/RIZZ*SF17*SF20/SF29
      COEFA(15,IA)=S*COEFA(15,IA)/RMASS*SF20/(SF22*SF7)
      COEFA(16,IA)=S*B*COEFA(16,IA)/RIXX*SF20/(SF22*SF27)
      COEFA(17,IA)=S*B*COEFA(17,IA)/RIZZ*SF20/(SF22*SF29)
      COEFA(18,IA)=S*COEFA(18,IA)/RMASS*SF20/(SF24*SF7)
      COEFA(19,IA)=S*B*COEFA(19,IA)/RIXX*SF20/(SF24*SF27)
      COEFA(20,IA)=S*B*COEFA(20,IA)/RIZZ*SF20/(SF24*SF29)
      COEFA(21,IA)=-S*COEFA(21,IA)/RMASS*SF20/(SF23*SF7)
      COEFA(22,IA)=S*CB*COEFA(22,IA)/RIYY*SF20/(SF23*SF28)
```

```
      C0EFA(23,IA)=-S*C0EFA(23,IA)/RMASS*SF20/(SF23*SF7)
      C0EFA(24,IA)=S*CB*C0EFA(24,IA)/RIYY*SF20/(SF23*SF28)
 5003 C0NTINUE
      IF(TEST(7).GT.0) G0 T0 751
      D0 750 I=1,4
      WRITE(6,761)
      WRITE(6,700)I
      WRITE(6,701)(DEGB(J),J=1,9)
      WRITE(6,702)
      D0 749 IA=1,15
      WRITE(6,703)DEGA(IA),(C0EFAB(I,IA,IB),IB=1,9)
  749 C0NTINUE
      WRITE(6,107)
      WRITE(6,780)
  750 C0NTINUE
      D0 751 I=1,7,2
      IPLS=I+1
      WRITE(6,763)
      WRITE(6,704)
      WRITE(6,705)
      WRITE(6,706)(J,J=KK(I),KK(IPLS))
      D0 752 IA=1,15
      WRITE(6,707)DEGA(IA),(C0EFA(J,IA),J=KK(I),KK(IPLS))
  752 C0NTINUE
      WRITE(6,107)
      WRITE(6,780)
  751 C0NTINUE
      CALL SETLINES(1,RIXZ,2,RIYY-RIZZ,3,RIZZ-RIXX,4,RIXX-RIYY)
************************************************************************
*                                                                      *
*                            SETP0T R0UTINE                            *
*                                                                      *
************************************************************************
      P0T(0)=SF5*ABS(RIXZ)/RIXX/SF4
      P0T(1)=SF5*SF6/(10.*SF4)*ABS(RIYY-RIZZ)/RIXX/SF4
```

```
PØT(2)=SF4/10.
PØT(3)=SF4*SF4/SF5*ABS(RIXZ)/RIYY/SF5
PØT(4)=SF4*SF6/(10.*SF5)*ABS(RIZZ-RIXX)/RIYY/SF5
PØT(5)=SF5/10.
PØT(6)=SF5*ABS(RIXZ)/RIZZ/SF6
PØT(7)=SF4*SF5/(10.*SF6)*ABS(RIXX-RIYY)/RIZZ/SF6
PØT(10)=SF6/10.
PØT(11)=.1*SF4/(SF5*SF6)*SF4
PØT(12)=.1*SF6/(SF4*SF5)*SF6
PØT(13)=.3270
PØT(14)=T/RMASS/SF7/10./.3166
PØT(15)=.0260
PØT(16)=ABS(SX0)/SF13
PØT(17)=.5000
PØT(20)=ABS(SZ0)/SF15
PØT(21)=SF1/SF13
PØT(22)=SF2/SF14
PØT(23)=SF3/SF15
PØT(24)=.1*180./3.1416*SF5/SF11
PØT(25)=.1*180./3.1416*SF5/SF8
PØT(26)=.1*180./3.1416*SF6/SF9
PØT(27)=.1*180./3.1416*SF4/SF12
PØT(30)=.1*180./3.1416*SF6/SF10
PØT(31)=SF7/SF1
PØT(32)=V0/SF1
PØT(33)=RHØ*SF19
PØT(34)=.1/.5730
PØT(35)=.1/.5435
PØT(36)=.0016
PØT(37)=.1/.4335
PØT(40)=.0962
PØT(41)=.2800
PØT(42)=A10/SF8
PØT(43)=.01*SF6*180./3.14159*SF30/SF18
PØT(44)=ABS(DIT0)/SF16
```

```
      PØT(45)=.1*SF6*SF6/(SF4*SF4)
      PØT(46)=WIND*6000./3600./SF13
      PØT(50)=SZF/SF15
      IF(TEST(7).GT.0) GØ TØ 12
      WRITE(6,9000)
      DØ 777 I=1,15,2
      IPLS=I+1
      WRITE(6,8001)KPØT(I),PØT(KPØT(I)),KPØT(IPLS),PØT(KPØT(IPLS))
  777 CØNTINUE
      DØ 778 I=17,39,2
      IPLS=I+1
      WRITE(6,8002)KPØT(I),PØT(KPØT(I)),KPØT(IPLS),PØT(KPØT(IPLS))
  778 CØNTINUE
      WRITE(6,107)
      WRITE(6,780)
      WRITE(6,122)
      WRITE(6,120)SF27,SF4,SF28,SF5,SF29,SF6,SF7,SF13,SF14,SF15,SF16,
     1SF11,SF17,SF9,SF12,SF20,SF10,SF1,SF18,SF8
      WRITE(6,123)
      WRITE(6,121)SF7,SF5,SF6,SF6,SF5,SF4,SF27,SF1,SF2,SF3,SF28,SF29
      WRITE(6,107)
   12 CALL PØTSET
      CALL SETPØT (4HP000,PØT(0),4HP001,PØT(1),4HP002,PØT(2),
     14HP003,PØT(3),4HP004,PØT(4),4HP005,PØT(5),4HP006,PØT(6),
     24HP007,PØT(7),4HP010,PØT(10),4HP011,PØT(11),4HP012,PØT(12),
     34HP013,PØT(13),4HP014,PØT(14),4HP015,PØT(15),4HP016,PØT(16),
     44HP017,PØT(17),4HP020,PØT(20),4HP021,PØT(21),4HP022,PØT(22),
     54HP023,PØT(23),4HP024,PØT(24),4HP025,PØT(25),4HP026,PØT(26),
     64HP027,PØT(27),4HP030,PØT(30),4HP031,PØT(31),4HP032,PØT(32),
     74HP033,PØT(33),4HP034,PØT(34),4HP035,PØT(35),4HP036,PØT(36),
     84HP037,PØT(37),4HP040,PØT(40),4HP041,PØT(41),4HP042,PØT(42),
     94HP043,PØT(43),4HP044,PØT(44),4HP045,PØT(45),4HP046,PØT(46),
     X4HP050,PØT(50))
 1001 CALL SETLINES(5,-1.0,6,+1.0)
*************************************************************************
```

```
*                                                                              *
*                            THE INSTRUCTIØNS                                  *
*                                                                              *
********************************************************************************
      CALL DTINIT(IDEV,ITDIR,20,IER)
      ENCØDE(16,311,ITEX11)
      ENCØDE(48,312,ITEX12)
      ENCØDE(32,313,ITEX13)
      ENCØDE(48,314,ITEX14)
      ENCØDE(48,315,ITEX15)
      ENCØDE(16,316,ITEX16)
      ENCØDE(44,317,ITEX17)
      ENCØDE(16,318,ITEX18)
      ENCØDE(48,319,ITEX19)
      ENCØDE(24,320,ITEX20)
      CALL TEXT8(IDEV,ITEX11,4,1,30,3,3,IER)
      CALL TEXT8(IDEV,ITEX12,12,7,1,2,3,IER)
      CALL TEXT8(IDEV,ITEX13,8,10,1,2,3,IER)
      CALL TEXT8(IDEV,ITEX14,12,16,1,2,3,IER)
      CALL TEXT9(IDEV,ITEX15,12,19,1,2,3,IER)
      CALL TEXT8(IDEV,ITEX16,4,22,1,2,3,IER)
      CALL TEXT8(IDEV,ITEX17,11,28,1,2,3,IER)
      CALL TEXT8(IDEV,ITEX18,4,31,1,2,3,IER)
      CALL TEXT8(IDEV,ITEX19,12,37,1,2,3,IER)
      CALL TEXT8(IDEV,ITEX20,6,40,1,2,3,IER)
      ND=0
      CALL RESET (1000)
  900 IF (TEST(2).GT.0) GØ TØ 900
      CALL SETLINES(5,+1.0,6,-1.0)
  805 IF (TEST(2).LT.0) GØ TØ 805
      CALL DTINIT(IDEV,ITDIR,20,IER)
      CALL DGINIT(IDEV,IDIR,3,IER)
      CALL GRAPH8(IDEV,ISG,52,1,IER)
********************************************************************************
*                                                                              *
```

```
*                                   THE LØØP                                    *
*                                                                               *
*********************************************************************************
 1000 IF (TEST(3).GT.0) GØ TØ 950
      CALL CØMPUTE
      CALL SETLINES(6,+1.0)
*********************************************************************************
*                                                                               *
*                                  A/D - D/A                                    *
*                                                                               *
*********************************************************************************
  950 CALL ADDA(AD,NAD,AA,NDA)
*********************************************************************************
*                                                                               *
*                             PREDICTØR AND UPDATE                              *
*                                                                               *
*********************************************************************************
      A(1)=A(1)+TAU*ADØTØ(1)*SF35
      A(2)=A(2)+TAU*ADØTØ(2)*SF36
      A(3)=A(3)+TAU*ADØTØ(3)*SF37
      A(4)=A(4)+TAU*ADØTØ(4)*SF38
      A(5)=A(5)+TAU*ADØTØ(5)*SF39
      V=V+TAU*VDØTØ*SF40
      P=P-TAU*PDØTN*SF4
      Q=Q-TAU*QDØTN*SF5
      R=R-TAU*RDØTN*SF6
      DØ 3400 I=1,5
      ADØTØ(I)=-ADØTN(I)
 3400 CØNTINUE
      VDØTØ=VDØT
*********************************************************************************
*                                                                               *
*                            SINE AND CØSINE LØØKUP                             *
*                                                                               *
*********************************************************************************
```

```
      DØ 3100 I=1,5
      ARG=A(I)*SFA(I)+91.0
      IARG=ARG
      SA(I)=TRIG(IARG)+(ARG-IARG)*(TRIG(IARG+1)-TRIG(IARG))
      CA(I)=TRIG(IARG+90)+(ARG-IARG)*(TRIG(IARG+91)-TRIG(IARG+90))
 3100 CØNTINUE
      PS=P*CA(1)+R*SA(1)*SF21
      RS=-P*SA(1)/SF21+R*CA(1)
      PSB=PS*B2/V
      QSB=QS*CB2/V
      RSB=RS*B2/V
      ADØTB(1)=-ADØTN(1)*CB2/V
************************************************************************
*                                                                      *
*                         CØEFFICIENT LØØKUP                           *
*                                                                      *
************************************************************************
      ALPHA=A(1)*SF8/5.0+6.0
      IALPHA=ALPHA
      BETA=A(2)*SF9/10.0+5.0
      IBETA=BETA
      IF(IALPHA.GT.14) IALPHA=14
      IF(IALPHA.LT.1) IALPHA=1
      IF(IBETA.GT.8) IBETA=8
      IF(IBETA.LT.1) IBETA=1
      DØ 3200 I=1,4
      C(I)=CØEFAB(I,IALPHA,IBETA)+(ALPHA-IALPHA)*(CØEFAB(I,IALPHA+1,IBET
     XA)-CØEFAB(I,IALPHA,IBETA))+(BETA-IBETA)*(CØEFAB(I,IALPHA,IBETA+1)-
     XCØEFAB(I,IALPHA,IBETA))
 3200 CØNTINUE
      DØ 3300 I=5,24
      C(I)=CØEFA(I,IALPHA)+(ALPHA-IALPHA)*(CØEFA(I,IALPHA+1)-CØEFA(I,IAL
     XPHA))
 3300 CØNTINUE
************************************************************************
```

```
*                                                                         *
*           RESØLUTIØN ØF AERØDYNAMIC FØRCES AND MØMENTS                  *
*                                                                         *
***************************************************************************
      FXAM=QUE*C(5)
      FYAM=QUE*(C(4)+RSB*C(18)+PSB*C(15)+DR*C(9)+DA*C(12))
      FZAM=QUE*(C(6)+QSB*C(21)+ADØTB(1)*C(23)+DIT*C(7))
      FXSM=(TM-GEE*SA(4))*CA(1)+GEE*CA(4)*CA(5)*SA(1)+FXAM
      FYSM=GEE*CA(4)*SA(5)+FYAM
      FZWM=-(TM-GEE*SA(4))*SA(1)+GEE*CA(4)*CA(5)*CA(1)+FZAM
      VDØT=FXSM*CA(2)+FYSM*SA(2)
      FYWM=-FXSM*SA(2)+FYSM*CA(2)
      ADØTN(1)=-FZWM*SF31/(V*CA(2))+PS*SA(2)*SF25/CA(2)-QS
      ADØTN(2)=-FYWM*SF32/V+RS
      ADØTN(3)=-(R*CA(5)+Q*SA(5)*SF26)/CA(4)
      ADØTN(4)=-Q*CA(5)+R*SA(5)/SF26
      ADØTN(5)=-P+ADØTN(3)*SA(4)*SF21
      ALSI=(C(1)+PSB*C(16)+RSB*C(19)+DA*C(13)+DR*C(10))*QUE
      AMI=(C(2)+QSB*C(22)+ADØTB(1)*C(24)+DIT*C(8))*QUE
      ANSI=(C(3)+PSB*C(17)+RSB*C(20)+DA*C(14)+DR*C(11))*QUE
      ALI=ALSI*CA(1)-ANSI*SA(1)*SF21
      ANI=ALSI*SA(1)/SF21+ANSI*CA(1)
      SDØT(1)=V*CA(4)*CA(3)
      SDØT(2)=V*CA(4)*SA(3)*SF33
      SDØT(3)=V*(-SA(4)+SA(1)*CA(4)*CA(5))*SF34
      SX=-SXN*SF13
      SY=SYN*SF14
      SZ=-SZN*SF15
      AØA=A(1)*SF8
***************************************************************************
*                                                                         *
*        INITIALIZE AND CHØP RUNWAY IF AFT ØF VIEWING CØNE                *
*                                                                         *
***************************************************************************
      PP11=PP21=PP61=0.0
```

```
      PP31=PP41=PP51=RAMP
      IF(TEST(2,4).LT.0) GO TO 6000
      TX=((-SZ)*(SSA4*CON4+CCA4*CON5))/((CCA4*CON4-SSA4*CON5)*CCA3)
      TALPHA=SSA3/CCA3
      TP3=-SX-TX+TALPHA*(SY+PP22)
      TP4=-SX-TX+TALPHA*(SY)
      TP5=-SX-TX+TALPHA*(SY+PP62)
      IF(TP3.LT.PP31) PP31=TP3
      IF(TP4.LT.PP41) PP41=TP4
      IF(TP5.LT.PP51) PP51=TP5
      IF(TP3.LT.PP21) PP21=TP3
      IF(TP4.LT.PP11) PP11=TP4
      IF(TP5.LT.PP61) PP61=TP5
*************************************************************************
*                                                                       *
*                    BUILD TRANSFORMATION MATRIX                        *
*                                                                       *
*************************************************************************
      H2(1,1)=CCA3*CCA4
      H2(1,2)=SSA3*CCA5-CCA3*SSA4*SSA5
      H2(1,3)=SSA3*SSA5+CCA3*SSA4*CCA5
      H2(2,1)=-CCA4*SSA3
      H2(2,2)=CCA3*CCA5+SSA3*SSA4*SSA5
      H2(2,3)=CCA3*SSA5-SSA3*SSA4*CCA5
      H2(3,1)=-SSA4
      H2(3,2)=-CCA4*SSA5
      H2(3,3)=CCA4*CCA5
      DO 150 I=1,4
      DO 151 J=1,4
      Z(I,J)=H1(I,1)*H2(1,J)+H1(I,2)*H2(2,J)+H1(I,3)*H2(3,J)+H1(I,4)*H2(
     X4,J)
  151 CONTINUE
  150 CONTINUE
      DO 152 I=1,4
      DO 153 J=2,4
```

```
      H(I,J)=Z(I,1)*H3(1,J)+Z(I,2)*H3(2,J)+Z(I,3)*H3(3,J)+Z(I,4)*H3(4,J)
  153 C0NTINUE
  152 C0NTINUE
*****************************************************************
*                                                               *
*                    BUILD ARRAY 0F LINES                       *
*                                                               *
*****************************************************************
      B3=PP11*HH14+PP12*HH24+PP13*HH34+PP14*HH44
      XEND(6)=XSTART(1)=XSTART(7)=(PP11*HH12+PP12*HH22+PP13*HH32+PP14*HH
     X42)/B3
      YEND(6)=YSTART(1)=YSTART(7)=(PP11*HH13+PP12*HH23+PP13*HH33+PP14*HH
     X43)/B3
      B3=PP21*HH14+PP22*HH24+PP23*HH34+PP24*HH44
      XEND(1)=XSTART(2)=(PP21*HH12+PP22*HH22+PP23*HH32+PP24*HH42)/B3
      YEND(1)=YSTART(2)=(PP21*HH13+PP22*HH23+PP23*HH33+PP24*HH43)/B3
      B3=PP31*HH14+PP32*HH24+PP33*HH34+PP34*HH44
      XEND(2)=XSTART(3)=(PP31*HH12+PP32*HH22+PP33*HH32+PP34*HH42)/B3
      YEND(2)=YSTART(3)=(PP31*HH13+PP32*HH23+PP33*HH33+PP34*HH43)/B3
      B3=PP41*HH14+PP42*HH24+PP43*HH34+PP44*HH44
      XEND(7)=XEND(3)=XSTART(4)=(PP41*HH12+PP42*HH22+PP43*HH32+PP44*HH42
     X)/B3
      YEND(7)=YEND(3)=YSTART(4)=(PP41*HH13+PP42*HH23+PP43*HH33+PP44*HH43
     X)/B3
      B3=PP51*HH14+PP52*HH24+PP53*HH34+PP54*HH44
      XEND(4)=XSTART(5)=(PP51*HH12+PP52*HH22+PP53*HH32+PP54*HH42)/B3
      YEND(4)=YSTART(5)=(PP51*HH13+PP52*HH23+PP53*HH33+PP54*HH43)/B3
      B3=PP61*HH14+PP62*HH24+PP63*HH34+PP64*HH44
      XEND(5)=XSTART(6)=(PP61*HH12+PP62*HH22+PP63*HH32+PP64*HH42)/B3
      YEND(5)=YSTART(6)=(PP61*HH13+PP62*HH23+PP63*HH33+PP64*HH43)/B3
*****************************************************************
*                                                               *
*                      BUILD THE H0RIZ0N                        *
*                                                               *
*****************************************************************
```

```
      ASZ=ABS(SZ)
      YMID=(-A(4)*SF11-90.0+CØN1*ATAN(SQRT(ASZ)*CØN3/ASZ))/(DEGMAX*CCA5)
      D=2.5*SSA5
      XSTART(8)=2.5*CCA5
      YSTART(8)=YMID+D
      XEND(8)=-XSTART(8)
      YEND(8)=YMID-D
***********************************************************************
*                                                                     *
*                           SØFTWARE WINDØW                           *
*                                                                     *
***********************************************************************
      DØ 500 I=1,8
      IX1=XSTART(I)
      IX2=XEND(I)
      IY1=YSTART(I)
      IY2=YEND(I)
      IF(IX1.GE.1.AND.IX2.GE.1) GØ TØ 261
      IF(IX1.LE.-1.AND.IX2.LE.-1) GØ TØ 261
      IF(IY1.GE.1.AND.IY2.GE.1) GØ TØ 261
      IF(IY1.LE.-1.AND.IY2.LE.-1) GØ TØ 261
      IAGN=1
      X=XSTART(I)
      Y=YSTART(I)
      IX=IX1
      IY=IY1
      SLØPE=(YSTART(I)-YEND(I))/(XSTART(I)-XEND(I))
  201 IF(IX)211,212,213
  211 VINSCT=Y+SLØPE*(-1.-X)
  221 IF(ABS(VINSCT).LE.1.) GØ TØ 226
  223 IF(IY)224,261,225
  226 XTEMP=-1.
      GØ TØ 247
  224 HINSCT=X+(-1.-Y)/SLØPE
      YTEMP=-1.
```

```
222 IF(ABS(HINSCT).GT.1.) GO TO 261
    XTEMP=HINSCT
    GO TO 250
225 HINSCT=X+(1.-Y)/SLOPE
    YTEMP=1.
    GO TO 222
212 IF(IY)224,232,225
232 XTEMP=X
    YTEMP=Y
    GO TO 250
213 VINSCT=Y+SLOPE*(1.-X)
    IF(ABS(VINSCT).LE.1.) GO TO 246
    GO TO 223
246 XTEMP=1.
247 YTEMP=VINSCT
250 GO TO (251,260),IAGN
251 X=XEND(I)
    Y=YEND(I)
    IX=IX2
    IY=IY2
    IAGN=2
    XSTART(I)=XTEMP
    YSTART(I)=YTEMP
    GO TO 201
260 CONTINUE
    XEND(I)=XTEMP
    YEND(I)=YTEMP
    GO TO 500
261 XEND(I)=-1.
    XSTART(I)=-1.
    YEND(I)=-1.
    YSTART(I)=-1.
500 CONTINUE
************************************************************************
*                                                                      *
```

```
*                         BUILD MEATBALL DISPLAY ARRAY                          *
*                                                                               *
*********************************************************************************
      GS=CØN1*ATAN((-SZ+HMIR)/(-SX-XMIR))
      YMB=1.0+(GS-GSØ)*CØN2
      IF((YMB.GT.1.16).ØR.(YMB.LT.0.84)) GØ TØ 601
      IDE(18)=IPACK(-1.08,YMB,0)
      IDE(19)=IPACK(-1.12,YMB,1)
      IDE(20)=IPACK(-1.12,(YMB+.04),1)
      IDE(21)=IPACK(-1.08,(YMB+.04),1)
      IDE(22)=IPACK(-1.08,YMB,1)
      GØ TØ 604
  601 IDE(18)=IDE(19)=IDE(20)=IDE(21)=IDE(22)=0
*********************************************************************************
*                                                                               *
*                    BUILD RUNWAY AND HØRIZØN DISPLAY ARRAY                     *
*                                                                               *
*********************************************************************************
  604 IDE(2)  =IPACK(XSTART(1),YSTART(1),0)
      IDE(3)  =IPACK(XEND(1),YEND(1),1)
      IDE(4)  =IPACK(XSTART(2),YSTART(2),0)
      IDE(5)  =IPACK(XEND(2),YEND(2),1)
      IDE(6)  =IPACK(XSTART(3),YSTART(3),0)
      IDE(7)  =IPACK(XEND(3),YEND(3),1)
      IDE(8)  =IPACK(XSTART(4),YSTART(4),0)
      IDE(9)  =IPACK(XEND(4),YEND(4),1)
      IDE(10)=IPACK(XSTART(5),YSTART(5),0)
      IDE(11)=IPACK(XEND(5),YEND(5),1)
      IDE(12)=IPACK(XSTART(6),YSTART(6),0)
      IDE(13)=IPACK(XEND(6),YEND(6),1)
      IDE(14)=IPACK(XSTART(7),YSTART(7),0)
      IDE(15)=IPACK(XEND(7),YEND(7),1)
      IDE(16)=IPACK(XSTART(8),YSTART(8),0)
      IDE(17)=IPACK(XEND(8),YEND(8),1)
*********************************************************************************
```

```
*                                                                        *
*              BUILD ANGLE ØF ATTACK INDEXER DISPLAY ARRAY               *
*                                                                        *
**************************************************************************
      IF(AØA.LT.AØAF) GØ TØ 2001
      IF((AØA.GE.AØAF).AND.(AØA.LT.AØALF)) GØ TØ 2002
      IF((AØA.GE.AØALF).AND.(AØA.LE.AØALS)) GØ TØ 2003
      IF(AØA.GT.AØAS) GØ TØ 2004
      IF(ND.EQ.1) GØ TØ 8000
      ND=1
      IDE(23)=ISLØ(1)
      IDF(24)=ISLØ(2)
      IDE(25)=ISLØ(3)
      IDE(26)=IDØN(1)
      IDE(27)=IDØN(2)
      IDE(28)=IDØN(3)
      IDF(29)=IDØN(4)
      IDE(30)=IDØN(5)
      GØ TØ 8000
 2001 IF(ND.EQ.2) GØ TØ 8000
      ND=2
      IDE(23)=IFAST(1)
      IDE(24)=IFAST(2)
      IDE(25)=IFAST(3)
      IDE(26)=IDE(27)=IDE(28)=IDE(29)=IDE(30)=0
      GØ TØ 8000
 2002 IF(ND.EQ.3) GØ TØ 8000
      ND=3
      IDE(23)=IFAST(1)
      IDE(24)=IFAST(2)
      IDE(25)=IFAST(3)
      IDE(26)=IDØN(1)
      IDE(27)=IDØN(2)
      IDE(28)=IDØN(3)
      IDE(29)=IDØN(4)
```

```
      IDE(30)=IDØN(5)
      GØ TØ 8000
 2003 IF(ND.EQ.4) GØ TØ 8000
      ND=4
      IDE(23)=IDØN(1)
      IDE(24)=IDØN(2)
      IDE(25)=IDØN(3)
      IDE(26)=IDØN(4)
      IDE(27)=IDØN(5)
      IDE(28)=IDE(29)=IDE(30)=0
      GØ TØ 8000
 2004 IF(ND.EQ.5) GØ TØ 8000
      ND=5
      IDE(23)=ISLØ(1)
      IDE(24)=ISLØ(2)
      IDE(25)=ISLØ(3)
      IDE(26)=IDE(27)=IDE(28)=IDE(29)=IDE(30)=0
***********************************************************************
*                                                                     *
*                    DISPLAY THE CØMPLETED ARRAY                      *
*                                                                     *
***********************************************************************
 8000 CALL GRAPHØ(IDEV,IDE,30,2,IER)
 8051 IF(TEST(5).GT.0) GØ TØ 8051
      GØ TØ 1000
 6000 CALL HØLD
***********************************************************************
*                                                                     *
*                        THE LANDING RESULTS                          *
*                                                                     *
***********************************************************************
      SNKRT=SDØT(3)*SF3
      CALL DGINIT(IDEV,IDIR,3,IER)
      CALL DTINIT(IDEV,ITDIR,20,IER)
      ENCØDE(16,901,ITEX91)
```

```
      ENCØDE(20,902,ITEX92)
      ENCØDE(16,903,ITEX93)
      ENCØDE(28,904,ITEX94)
      ENCØDE(20,905,ITEX95)
      ENCØDE(24,908,ITEX98)
      ENCØDE(8,970,ITEX70)
      ENCØDE(16,972,ITEX72)
      ENCØDE(24,973,ITEX73)
      ENCØDE(8,974,ITEX74)
      ENCØDE(8,975,ITEX75)
      ENCØDE(12,976,ITEX76)
      ENCØDE(12,977,ITEX77)
      ENCØDE(12,978,ITEX78)
      CALL TEXTØ(IDEV,ITEX91,4,1,25,3,3,IER)
      IF(SNKRT.GT.20.0) GØ TØ 1200
      IF(-SX.GT.PP41) GØ TØ 1200
      IF(((-SX.GT.1.0).AND.(-SX.LE.PP41)).AND.(-SY.GT.PP62)) GØ TØ 1200
      IF(((-SX.GT.1.0).AND.(-SX.LE.PP41)).AND.(-SY.LT.PP22)) GØ TØ 1200
      IF(-SX.LE.1.0) GØ TØ 1201
      IF((-SX.GE.W1).AND.(-SX.LE.PP41)) GØ TØ 1206
      IF((-SX.GE.W2).AND.(-SX.LT.W1)) GØ TØ 1205
      IF((-SX.GE.W3).AND.(-SY.LT.W2)) GØ TØ 1204
      IF((-SX.GE.W4).AND.(-SX.LT.W3)) GØ TØ 1203
      IF(-SX.LT.W4) GØ TØ 1202
 1200 CALL TEXTØ(IDEV,ITEX92,5,5,22,3,3,IER)
      LL=-1
      GØ TØ 1300
 1201 CALL TEXTØ(IDEV,ITEX94,7,5,10,3,3,IER)
      LL=-1
      GØ TØ 1300
 1202 CALL TEXTØ(IDEV,ITEX93,4,5,25,3,3,IER)
      LL=1
      GØ TØ 1300
 1203 IWIRE=4
      GØ TØ 1220
```

```
1204 IWIRE=3
     GØ TØ 1220
1205 IWIRE=2
     GØ TØ 1220
1206 IWIRE=1
1220 CALL TEXTØ(IDEV,ITEX95,5,5,24,3,3,IER)
     ENCØDE(16,906,ITEX96)IWIRE
     CALL TEXTØ(IDEV,ITEX96,4,8,28,3,3,IER)
     LL=1
1300 IF((SNKRT.GT.18.0).AND.(SNKRT.LE.20.0).AND.(LL.GT.0)) CALL TEXTØ
    X(IDEV,ITEX98,6,13,18,3,3,IER)
     ENCØDE(28,907,ITEX97)SNKRT
     CALL TEXTØ(IDEV,ITEX97,7,18,9,3,3,IER)
     IF(LL.EQ.-1) GØ TØ 1399
     CALL TEXTØ(IDEV,ITEX70,2,23,37,3,3,IER)
     IF(SY.GT.1.0) GØ TØ 1310
     IF(SY.LT.-1.0) GØ TØ 1320
     CALL TEXTØ(IDEV,ITEX72,4,28,28,3,3,IER)
     GØ TØ 1399
1310 ENCØDE(32,909,ITEX99)SY
     CALL TEXTØ(IDEV,ITEX99,8,28,4,3,3,IER)
     GØ TØ 1399
1320 ENCØDE(32,971,ITEX71)-SY
     CALL TEXTØ(IDEV,ITEX71,8,28,3,3,3,IER)
1399 IF(LL.LT.0) GØ TØ 510
     CALL TEXTØ(IDEV,ITEX73,6,33,16,3,3,IER)
     IF(ND.EQ.1) GØ TØ 1401
     IF(ND.EQ.2) GØ TØ 1402
     IF(ND.EQ.3) GØ TØ 1403
     IF(ND.EQ.4) GØ TØ 1404
     CALL TEXTØ(IDEV,ITEX75,2,38,42,3,3,IER)
     GØ TØ 510
1401 CALL TEXTØ(IDEV,ITEX78,3,38,31,3,3,IER)
     GØ TØ 510
1402 CALL TEXTØ(IDEV,ITEX74,2,38,42,3,3,IER)
```

```
      GO TO 510
 1403 CALL TEXTO(IDEV,ITEX77,3,38,31,3,3,IER)
      GO TO 510
 1404 CALL TEXTO(IDEV,ITEX76,3,38,36,3,3,IER)
*************************************************************************
*                                                                       *
*                         PROGRAM OPTIONS                               *
*                                                                       *
*************************************************************************
  510 I=1000000
      CALL DELAY
      CALL DTINIT(IDEV,ITDIR,20,IER)
      CALL DGINIT(IDEV,IDIR,3,IER)
      ENCODE(32,143,ITEX43)
      ENCODE(24,145,ITEX45)
      ENCODE(28,146,ITEX46)
      ENCODE(24,147,ITEX47)
      ENCODE(16,148,ITEX48)
      CALL TEXTO(IDEV,ITEX43,8,7,4,3,3,IER)
      CALL TEXTO(IDEV,ITEX45,6,10,16,3,3,IER)
      CALL TEXTO(IDEV,ITEX46,7,17,9,3,3,IER)
      CALL TEXTO(IDEV,ITEX47,6,20,14,3,3,IER)
      CALL TEXTO(IDEV,ITEX48,4,23,24,3,3,IER)
  509 IF (TEST(2).LT.0) GO TO 509
      CALL SETLINES(5,-1.0,6,-1.0)
    2 IF (TEST(3).LT.0) GO TO 1001
      IF (TEST(2).GT.0) GO TO 2
      CALL SETLINES(5,+1.0,6,+1.0)
  512 CALL DGINIT(IDEV,IDIR,3,IER)
      CALL DTINIT(IDEV,ITDIR,20,IER)
      ENCODE(32,130,ITEX30)
      ENCODE(28,131,ITEX31)
      ENCODE(44,132,ITEX32)
      ENCODE(28,133,ITEX33)
      ENCODE(48,134,ITEX34)
```

```
      ENCØDE(44,135,ITEX35)
      ENCØDE(12,136,ITEX36)
      ENCØDE(48,137,ITEX37)
      ENCØDE(44,138,ITEX38)
      ENCØDE(44,139,ITEX39)
      ENCØDE(8,140,ITEX40)
      ENCØDE(28,141,ITEX41)
      ENCØDE(20,142,ITEX42)
      CALL TEXTØ(IDEV,ITEX30,8,1,8,2,3,IER)
      CALL TEXTØ(IDEV,ITEX31,7,3,8,2,3,IER)
      CALL TEXTØ(IDEV,ITEX32,11,7,1,2,3,IER)
      CALL TEXTØ(IDEV,ITEX33,7,9,4,2,3,IER)
      CALL TEXTØ(IDEV,ITEX34,12,13,1,2,3,IER)
      CALL TEXTØ(IDEV,ITEX35,11,15,4,2,3,IER)
      CALL TEXTØ(IDEV,ITEX36,3,17,4,2,3,IER)
      CALL TEXTØ(IDEV,ITEX37,12,21,1,2,3,IER)
      CALL TEXTØ(IDEV,ITEX38,11,23,4,2,3,IER)
      CALL TEXTØ(IDEV,ITEX39,11,25,4,2,3,IER)
      CALL TEXTØ(IDEV,ITEX40,2,27,4,2,3,IER)
      CALL TEXTØ(IDEV,ITEX41,7,31,1,2,3,IER)
      CALL TEXTØ(IDEV,ITEX42,5,33,1,2,3,IER)
      NULL(1)=NULL(2)=77777777B
      CALL TEXTR(IDEV,NULL,2,32,60,3,3,IER)
  511 IF(MØD(ITDIR(14),8).EQ.0) GØ TØ 511
      CALL TEXTI(IDEV,CHØYC,2,0,14,IER)
  631 FØRMAT(F8.7)
      DECØDE(8,631,CHØYC)CHØYC
      ICHØYC=CHØYC
      IF(ICHØYC.LT.1) ICHØYC=4
      GØ TØ (8004,1001,8003,513),ICHØYC
  513 CALL DGINIT(IDEV,IDIR,3,IER)
      CALL DTINIT(IDEV,ITDIR,20,IER)
      ENCØDE(24,144,ITEX44)
      CALL TEXTØ(IDEV,ITEX44,6,20,16,3,3,IER)
      I=300000
```

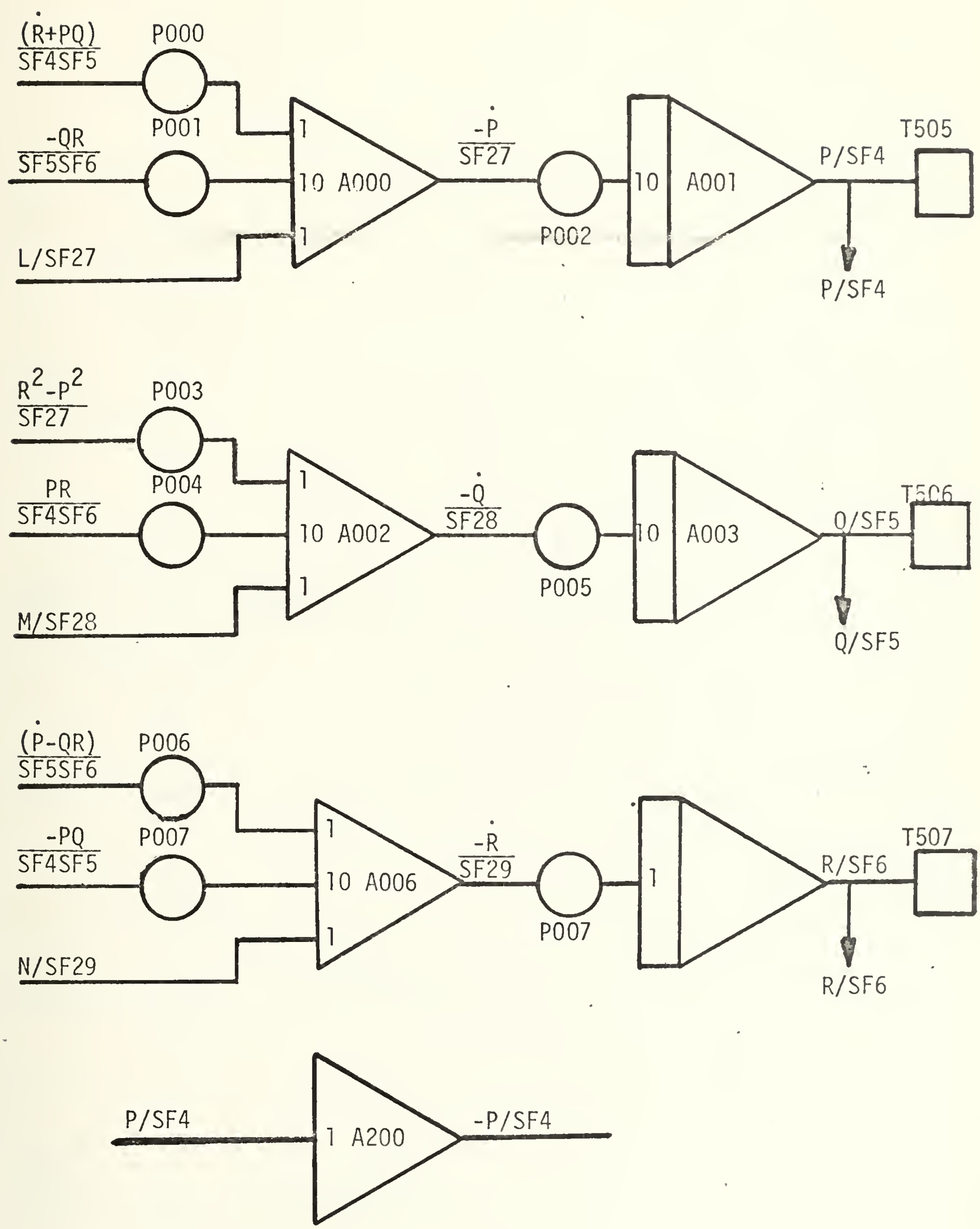
```
      CALL DELAY
      GØ TØ 512
8004  CALL PØTSET
      CALL DTINIT(IDEV,ITDIR,20,IER)
      CALL DGINIT(IDEV,IDIR,3,IER)
      STØP
      END
```

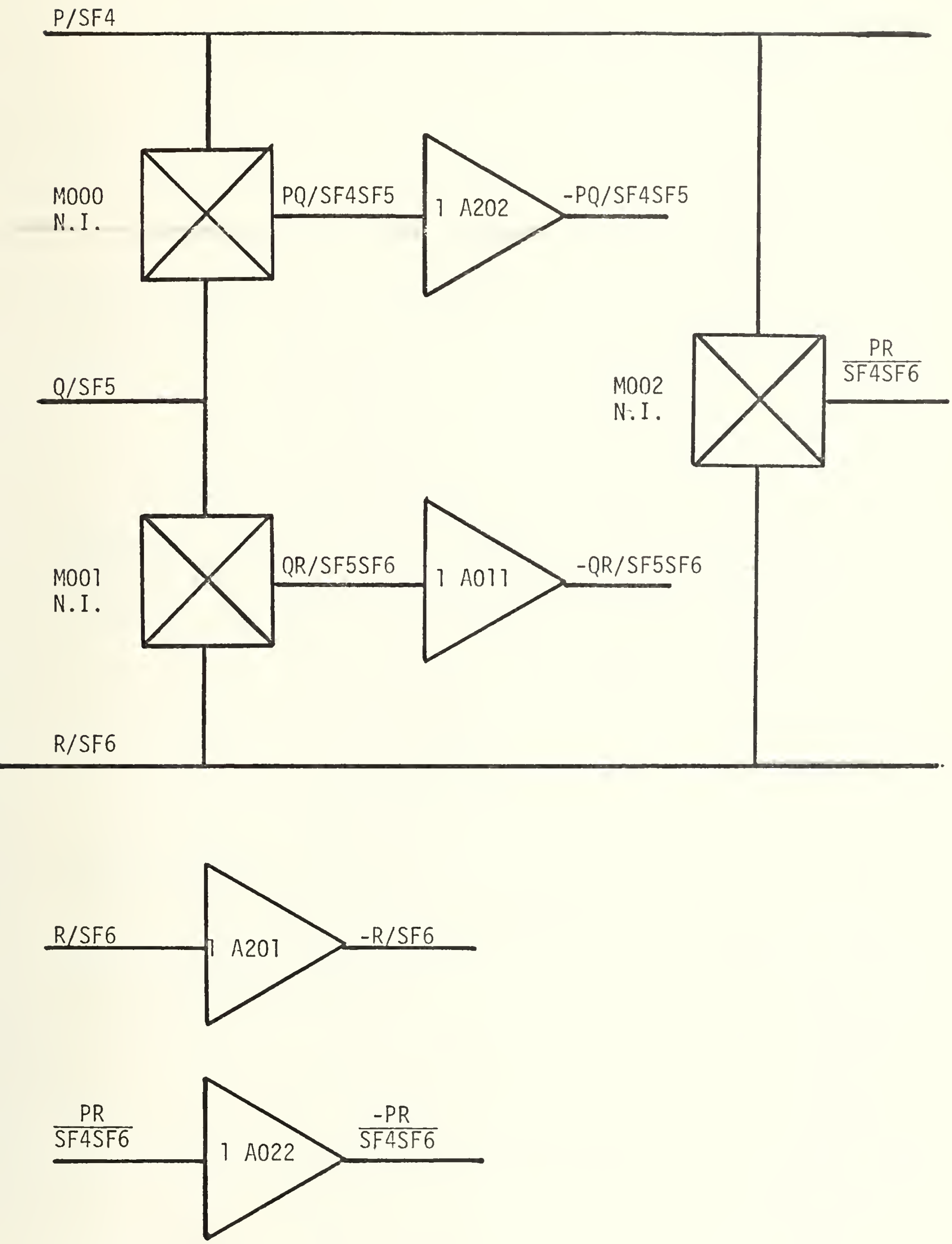
```
*****************************************************************************
*                                                                           *
*                          SUBR0UTINE ADDA                                  *
*                                                                           *
*****************************************************************************
X1      EQU     1
X2      EQU     2
A       EQU     5
B       EQU     4
$ADDA   PZE
        BRM     9SETUPN
        PZE     4
AD      PZE
NAD     PZE
DA      PZE
NDA     PZE
        SKR     FINFLG
        BRU     $-1
        LDA     BRMFIN
        STA     040
        STA     041
        LDA     *NAD
        STA     C0UNT
        SKR     C0UNT
        BRU     $+2
        BRU     DT0A
        LLSA    15
        ADD     =ADC0M
        STA     ADCW
        SKN     FINFLG
        BRU     $-1
        STZ     FINFLG
        E0M     034001
        P0T     ADCW
        LDX     =00100000,1
```

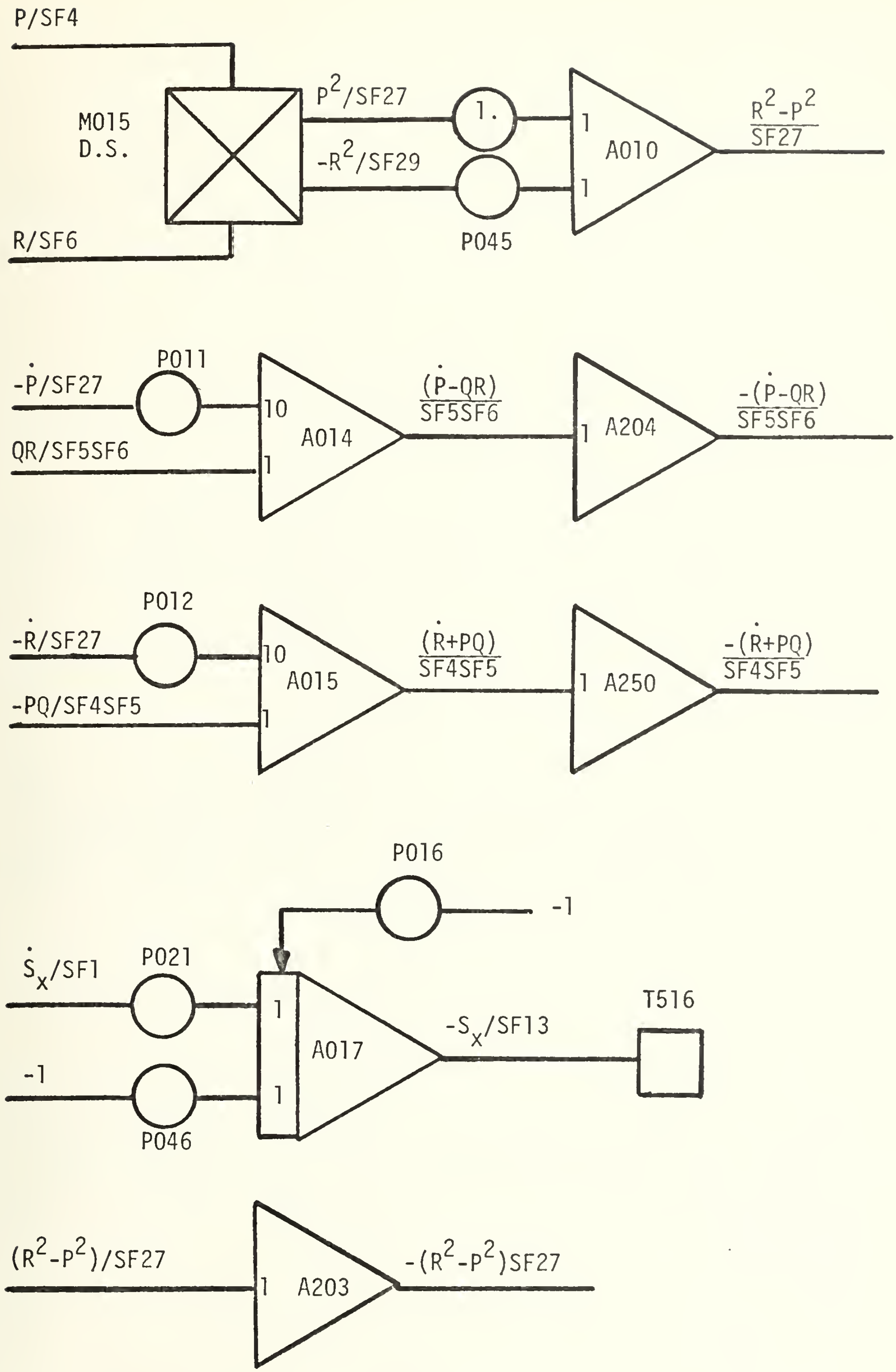
```
        SKN     FINFLG
        BRU     $-1
ITØR    LDA     ADBUF,1
        CØPY    (O,B)
        FLA     O.O
        STD     *AD
        MPT     AD
        SKR     CØUNT
        BRX     ITØR,1
DTØA    LDA     *NDA
        MRG     =077700000
        CØPY    (A,X1)
        CØPY    (O,A)
        STA     DACØM,1
        BRX     $+2,1
        BRR     ADDA
        STZ     DCH
        BRU     $+2
RTØI    MPT     DA
        MPØ     DCH
        LDP     *DA
        CRSD    9
        ARSD    15
        CØPY    (-A,A)
        CØPY    (A,X2)
        CØPY    (B,A)
        ARSA    0,2
        ETR     =077777000
        ADD     DCH
        STA     DACØM,1
        BRX     RTØI,1
        STZ     FINFLG
        LDA     *NDA
        LLSA    15
        ADD     =DACØM
```

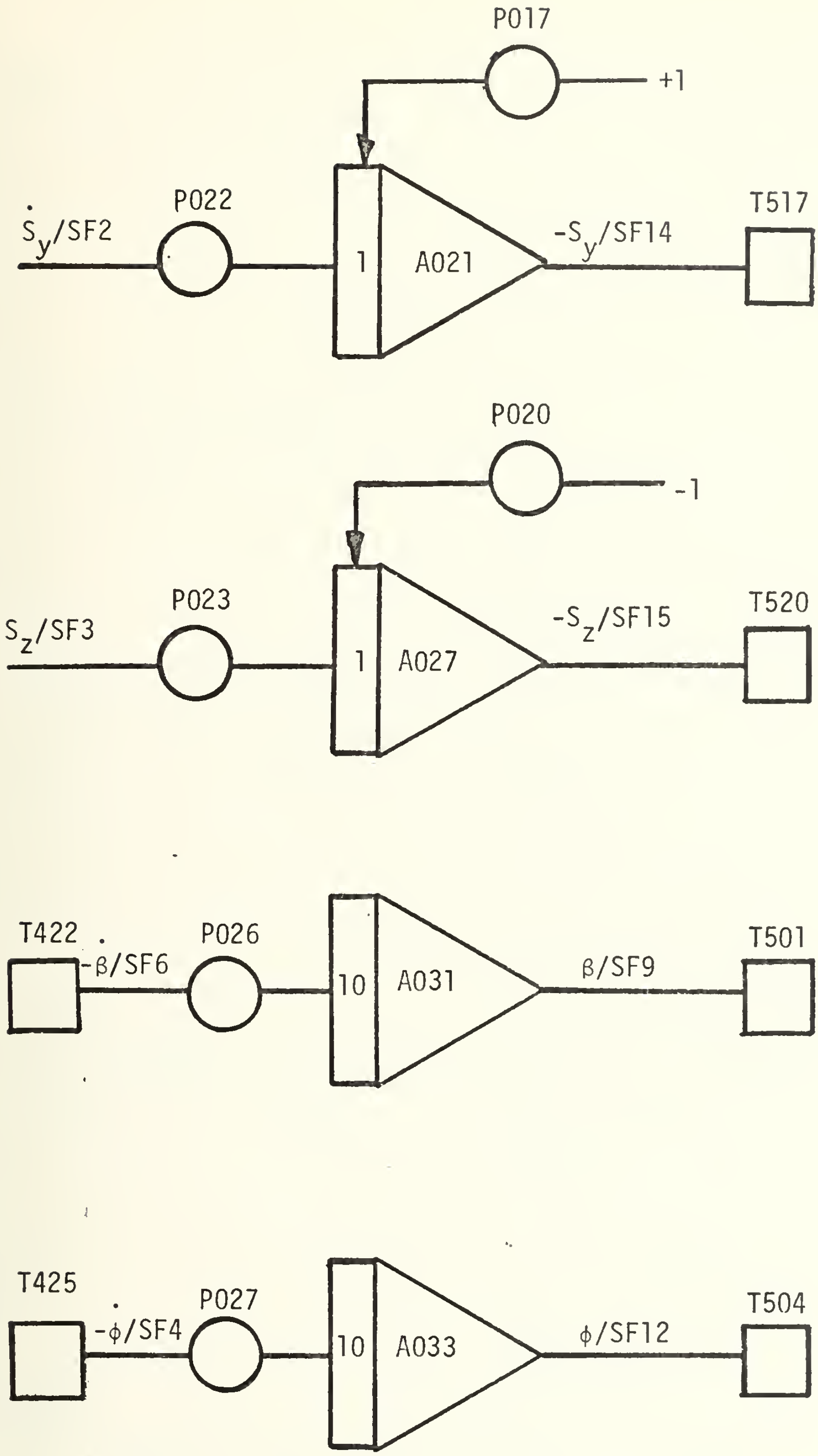
```
         STA     DACW
         EØM     035001
         PØT     DACW
         BRR     ADDA
BRMFIN   BRM     FIN
FIN      PZE
         SKR     FINFLG
         BRU     $-1
         BRC     *FIN
FINFLG   PZE
DCH      PZE
CØUNT    PZE
CØN      FØRM    9,15
ADCW     PZE
ADCØM    CØN     0,ADBUF
         DATA    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
         DATA    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
ADBUF    RES     32
DACW     PZE
DACØM    RES     13
         END
```

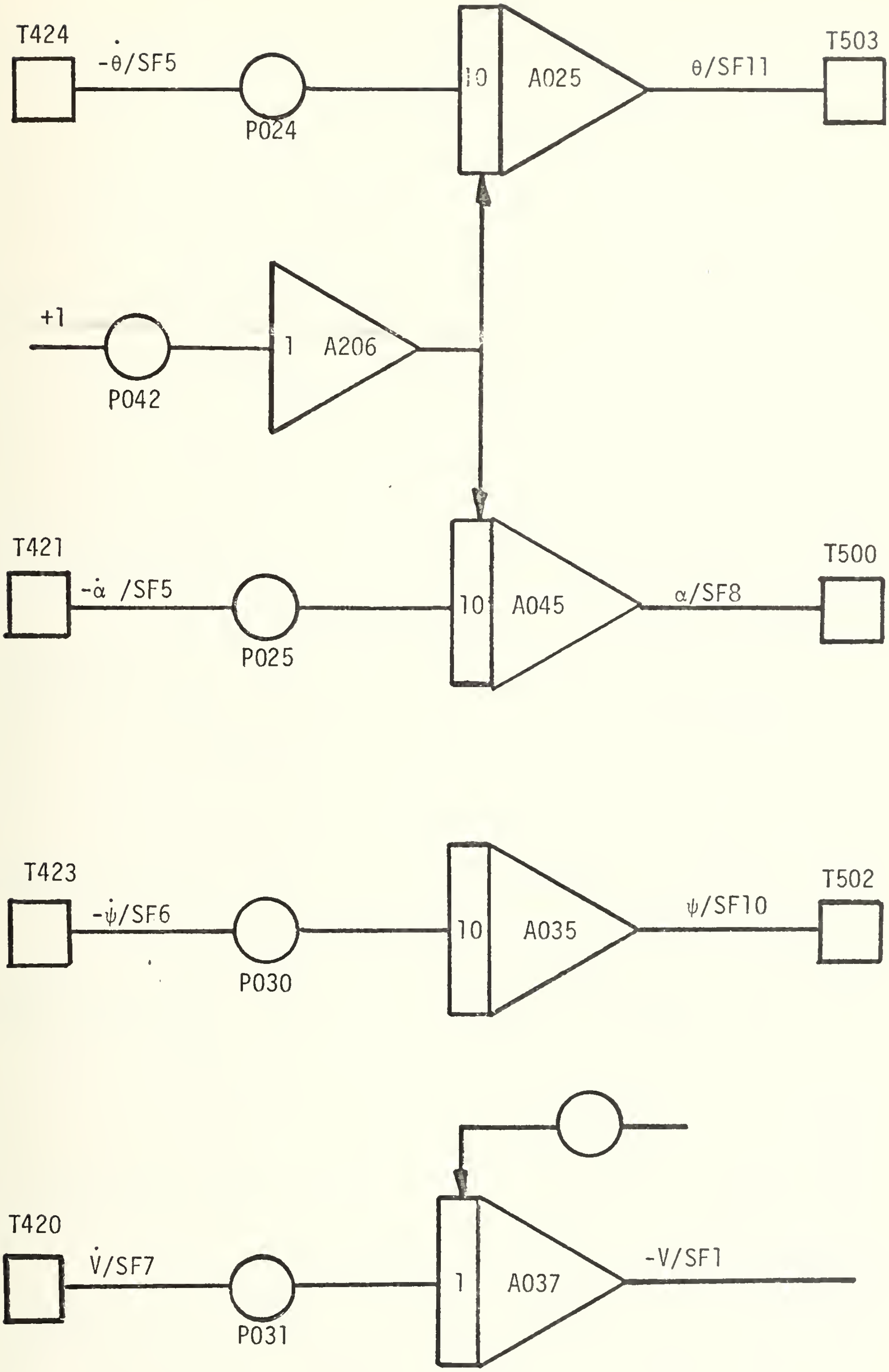
APPENDIX B - THE ANALOG PROGRAM

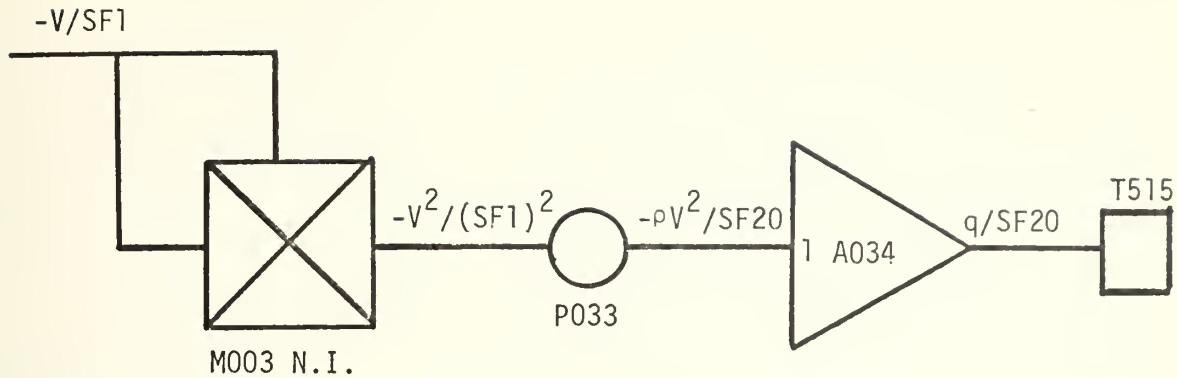



P/SF4
M000
N.I.
PQ/SF4SF5
1 A202
-PQ/SF4SF5
Q/SF5
M002
N.I.
PR/SF4SF6
M001
N.I.
QR/SF5SF6
1 A011
-QR/SF5SF6
R/SF6
R/SF6
1 A201
-R/SF6
PR/SF4SF6
1 A022
-PR/SF4SF6

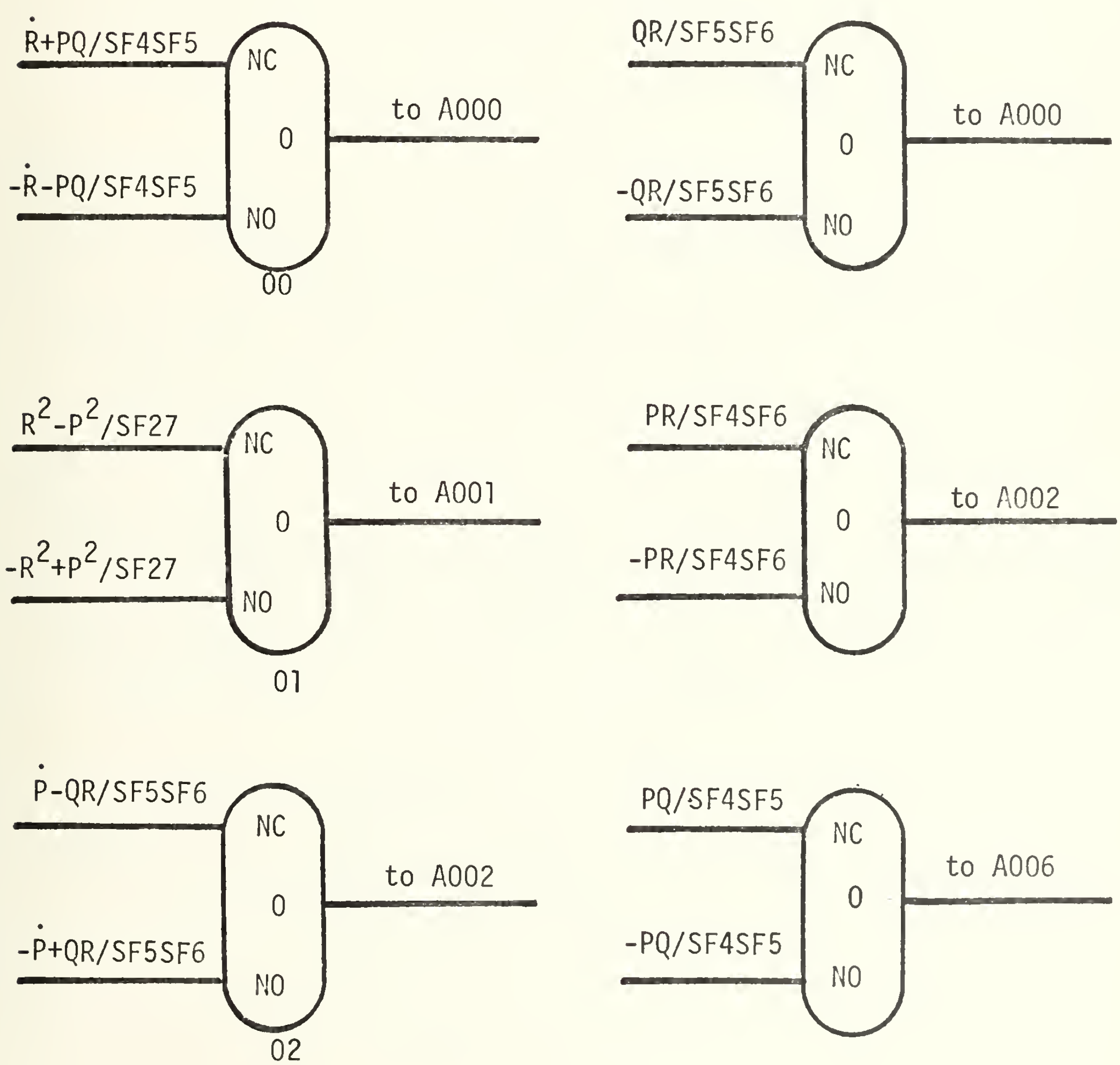

P/SF4
M015
D.S.
R/SF6
P^2/SF27
$-R^2$/SF29
1.
P045
1
1
A010
$\frac{R^2-P^2}{SF27}$
P011
$-\dot{P}$/SF27
QR/SF5SF6
10
1
A014
$\frac{(\dot{P}-QR)}{SF5SF6}$
1
A204
$-\frac{(\dot{P}-QR)}{SF5SF6}$
P012
$-\dot{R}$/SF27
-PQ/SF4SF5
10
1
A015
$\frac{(\dot{R}+PQ)}{SF4SF5}$
1
A250
$-\frac{(\dot{R}+PQ)}{SF4SF5}$
P016
-1
$\dot{S}_x$/SF1
P021
-1
P046
1
1
A017
$-S_x$/SF13
T516
(R^2-P^2)/SF27
1
A203
$-(R^2-P^2)$SF27

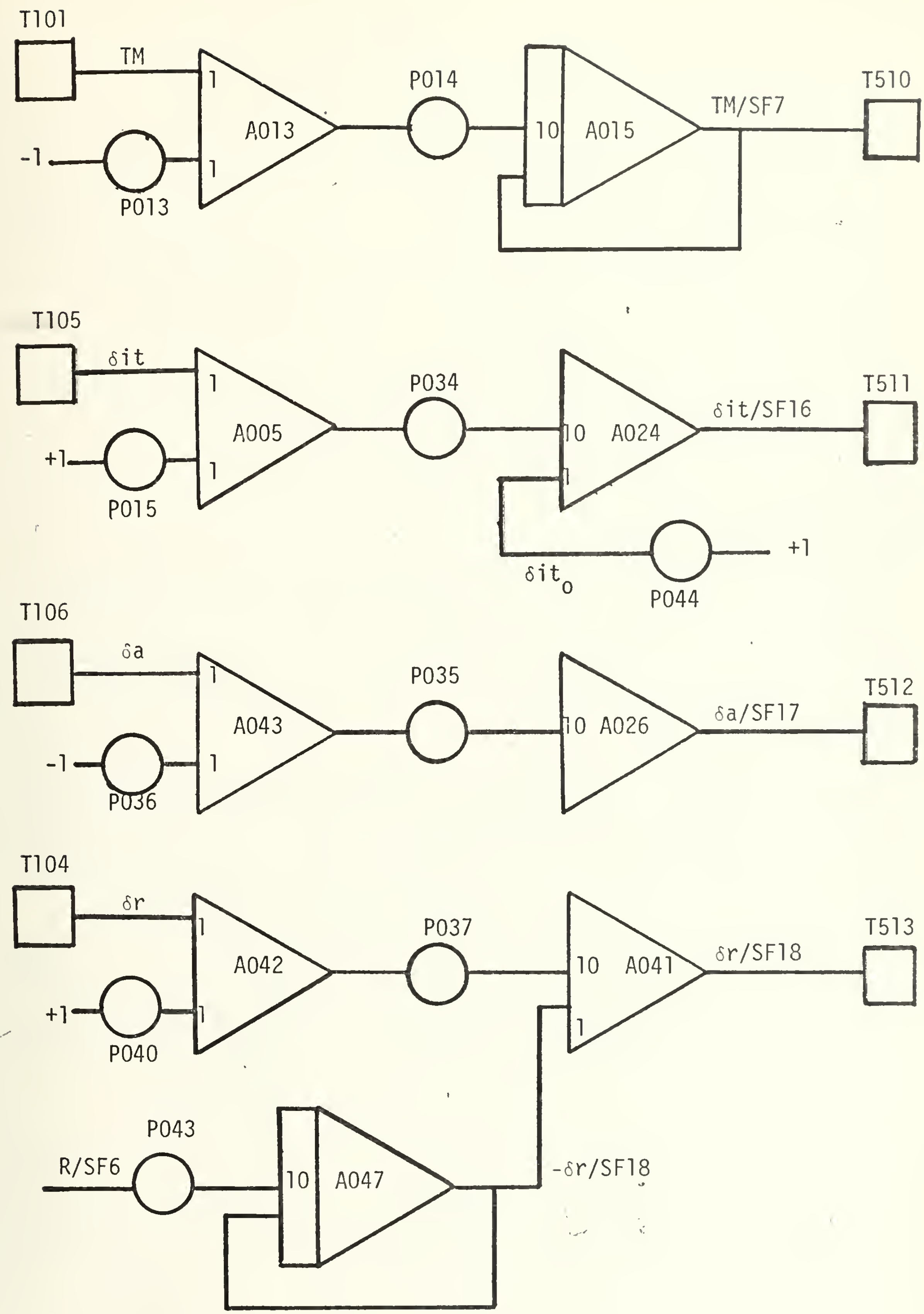

P017
+1
P022
$\dot{S}_y$/SF2
1
A021
$-S_y$/SF14
T517
P020
-1
P023
S_z/SF3
1
A027
$-S_z$/SF15
T520
T422
$-\dot{\beta}$/SF6
P026
10
A031
β/SF9
T501
T425
$-\dot{\phi}$/SF4
P027
10
A033
ϕ/SF12
T504


T424
-θ/SF5
P024
10
A025
θ/SF11
T503
+1
P042
1
A206
T421
-α̇ /SF5
P025
10
A045
α/SF8
T500
T423
-ψ̇/SF6
P030
10
A035
ψ/SF10
T502
T420
V̇/SF7
P031
1
A037
-V/SF1



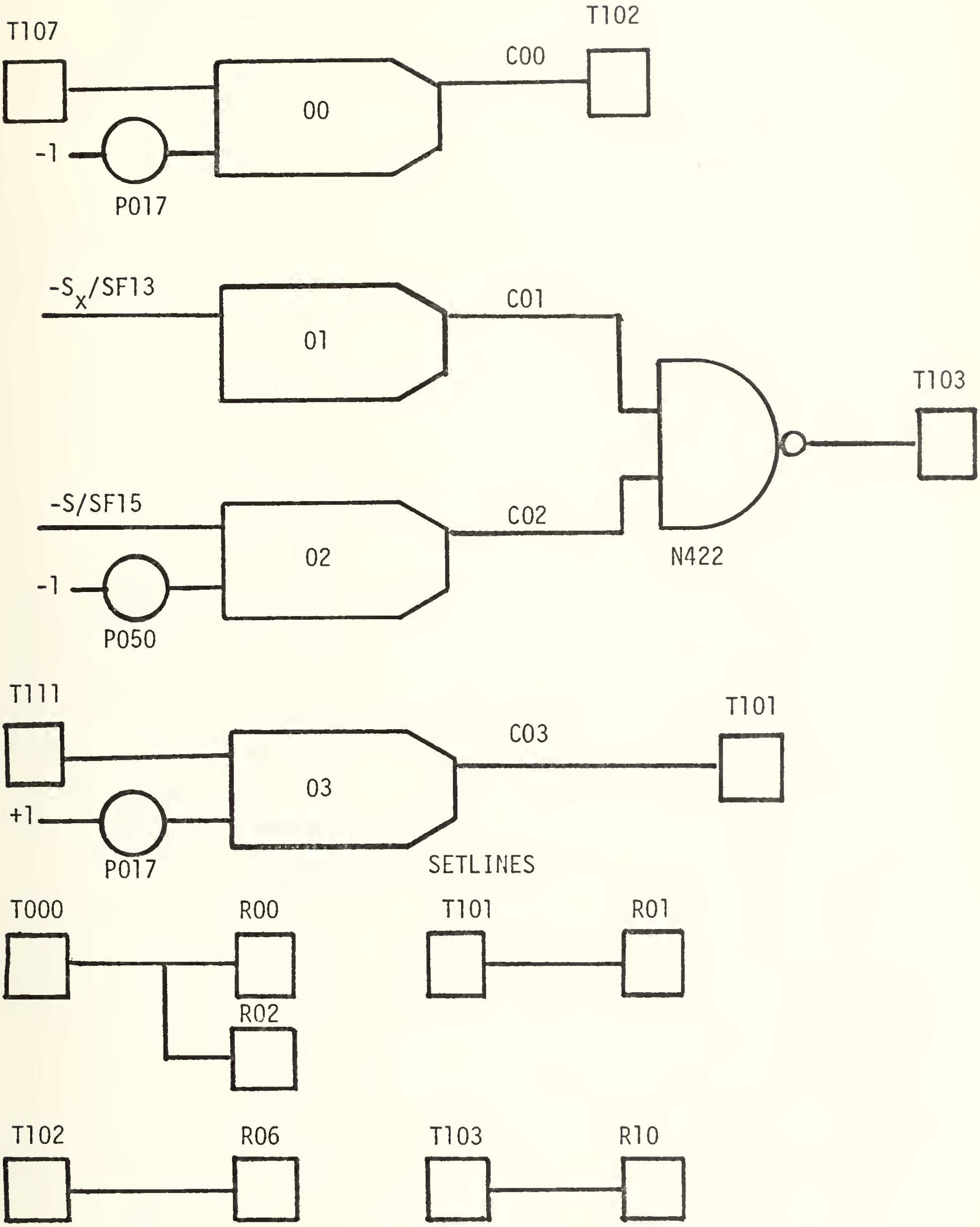
DPDT SWITCHES

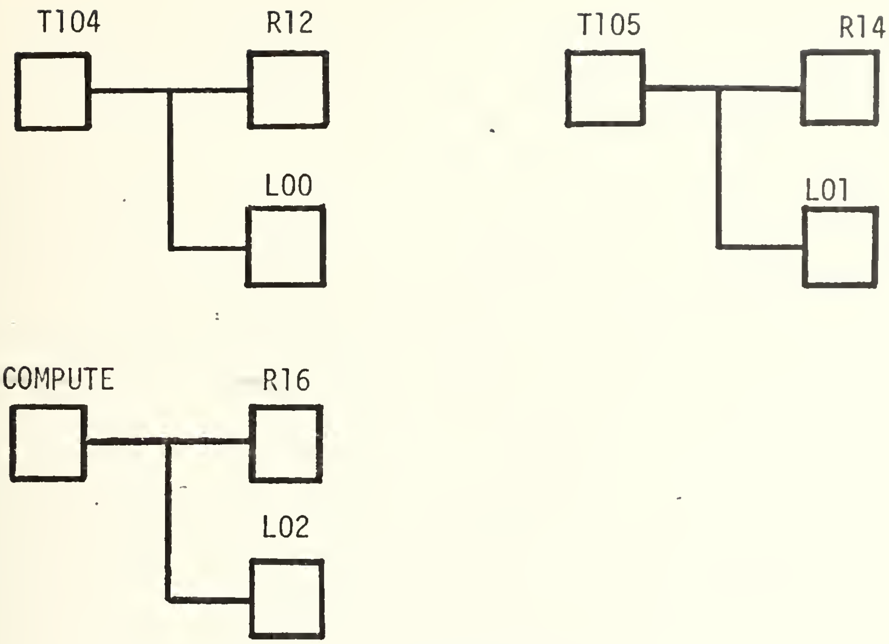




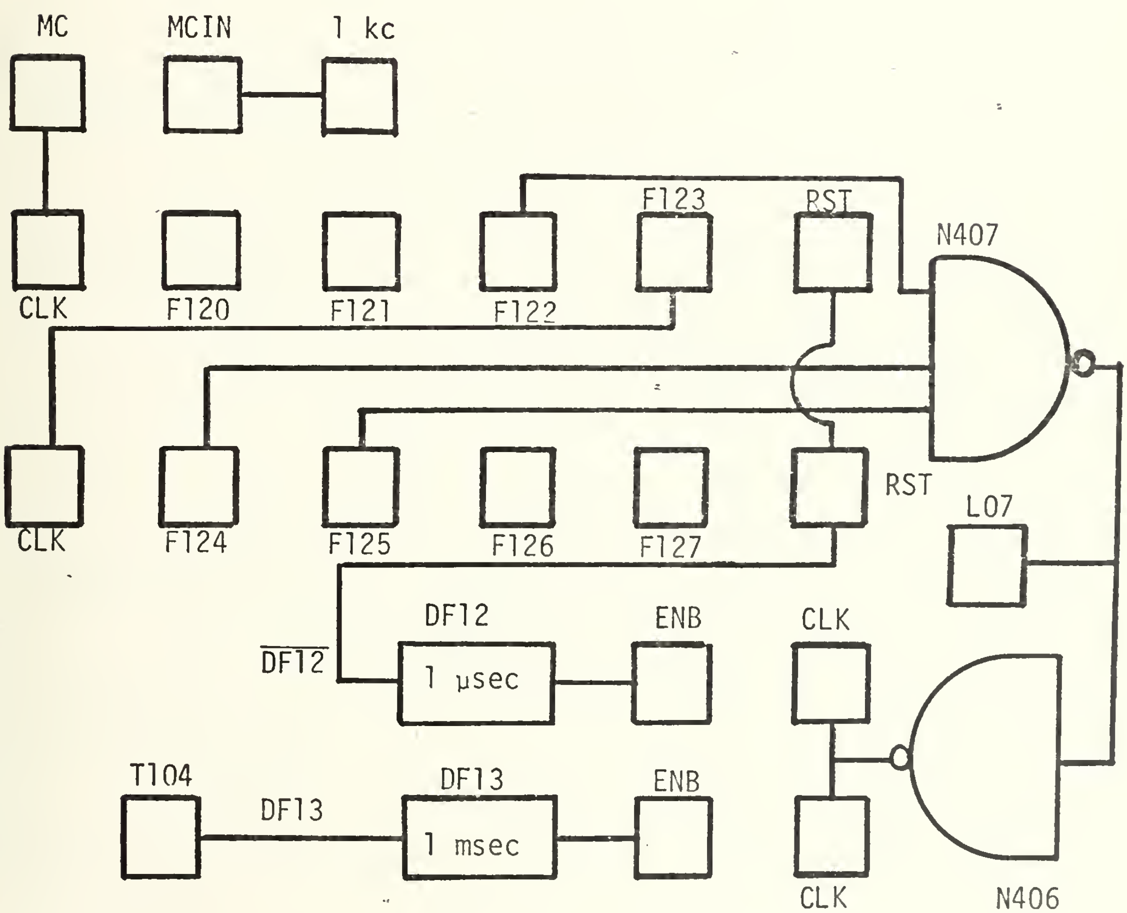
T101
TM
1
1
-1
A013
P013
P014
10
A015
TM/SF7
T510
T105
δit
1
1
+1
A005
P015
P034
10
1
A024
δit/SF16
T511
δit_o
P044
+1
T106
δa
1
1
-1
A043
P036
P035
10
A026
δa/SF17
T512
T104
δr
1
1
+1
A042
P040
P037
10
1
A041
δr/SF18
T513
P043
R/SF6
10
A047
-δr/SF18

COMPARATORS

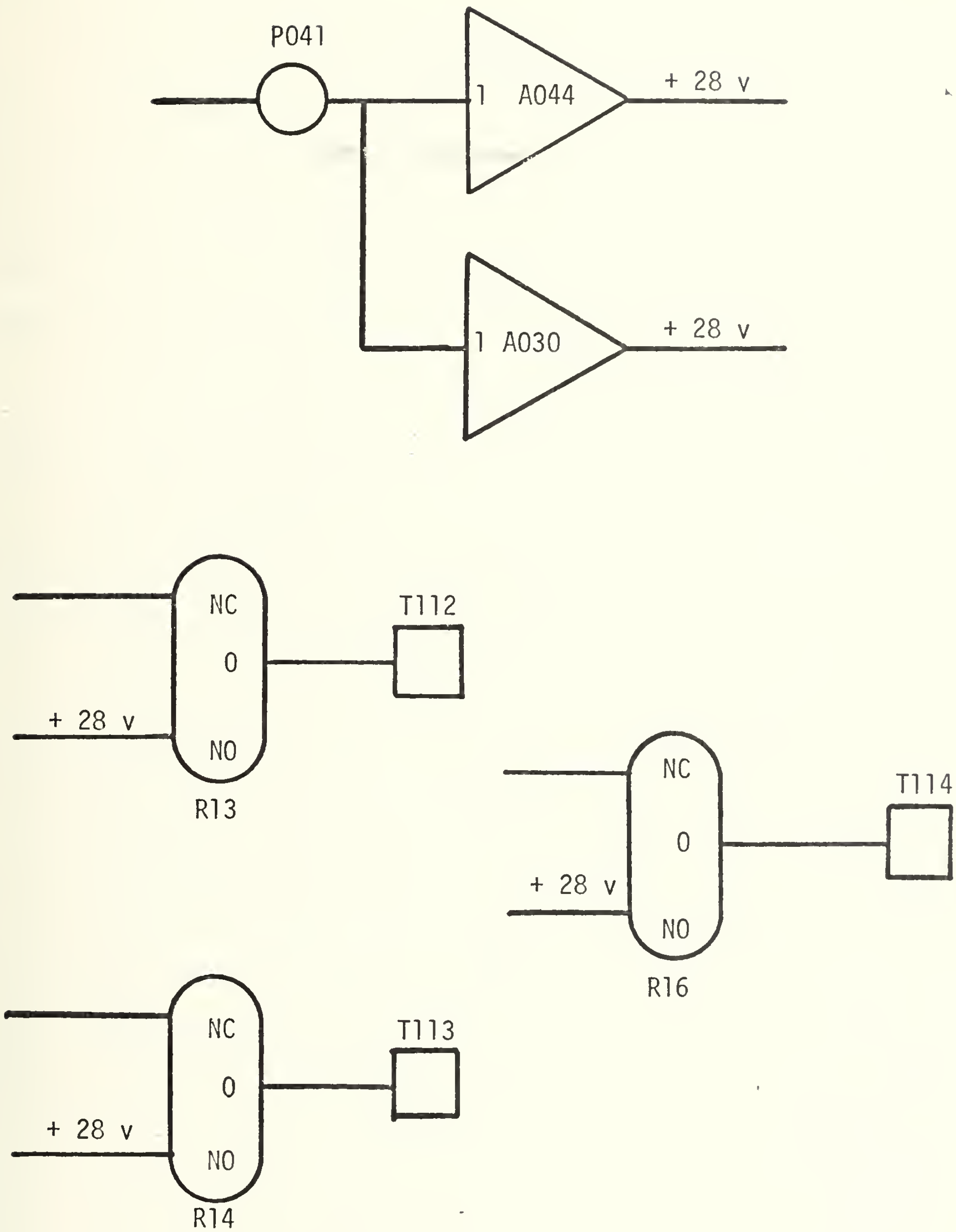




BINARY COUNTER



POWER FOR LIGHTS



APPENDIX C - PROGRAM VARIABLES

The following is an alphabetic listing of the program variables used in the simulator program.

A - Array of angles, in order, alpha, beta, psi, theta, and phi

A10 - Initial conditions on A(1), the angle of attack

AA - Array of analog to digital variables

AD - Array of analog to digital variables

ADOTB - Normalized time derivitive of the angle of attack

ADOTN - Array of the negatives of the time derivitatives of the angles in A

ADOTO - Temporary storage for ADOTN during the predict and update phase of the program

ALI - Aerodynamic rolling moment about the body axis

ALPHA - Real argument based on angle of attack and used for coefficient lookup

ALSI - Aerodynamic rolling moment about the stability axis

AMI - Aerodynamic pitching moment about the body axis

ANI - Aerodynamic yawing moment about the body axis

ANSI - Aerodynamic yawing moment about the stability axis

AOA - Actual angle of attack in degrees

AOAF - Angle of attack break point for fast cheveron

AOALDG - Optimum landing angle of attack

AOALF - Angle of attack break point for fast cheveron and donut

AOALS - Angle of attack break point for slow cheveron

ARG - Argument used during sine and cosine lookup (type real)

ASZ - Absolute value of SZ

B - Wing span

B2 - One half the wing span B

B3 - Scale factor divisor used to divide out the scale factor of the homogeneous transformation coordinates

BETA - Real argument based on side slip angle used in coefficient lookup

C - Array of aerodynamic coefficients for a given angle of attack and sideslip angle

CA - Array of cosines of the angle array A

CB - Mean aerodynamic chord

CB2 - One half the mean aerodynamic chord CB

CCA(n) - Scalar equivalents of the array CA

CHOYC - Choice of program options offered by main program

COEFA - Array of coefficients dependent on angle of attack only

COEFAB - Array of coefficients dependent on angle of attack and side slip angle

CON1 - Program constant equal to the number of degrees in a radian

CON2 - Program constant equal to .2 divided by .75

CON3 - Program constant used in computing the depression angle of the horizon

CON4 - Program constant equal to the sine of 30 degrees

CON5 - Program constant equal to the cosine of 30 degrees

CON6 - Program constant equal to the ratio of CON3 to CON5

D - Constant equal to 2.5 times the sine of the roll angle and used in calculating the horizon

DA - Aileron deflection

DEGA - Degrees of angle of attack for which COEFA and COEFAB are tabulated

DEGB - Degrees of side slip for which COEFAB are tabulated

DEGMAX - Max angle of the visibility cone formed by the square viewing window

DIT - Flying tail deflection

DITO - Initial flying tail deflection setting

DR - Rudder deflection

F - Focal length of viewing image

FXAM - Aerodynamic force in the X-direction divided by the mass of the aircraft

FXSM - Force in X-direction of the stability axis divided by the mass of the aircraft

FYAM - Aerodynamic force in the Y-direction divided by the mass of the aircraft

FYSM - Force in the Y-direction of the stability axis divided by the mass of the aircraft

FYWM - Force in the Y-direction of the wind axis divided by the mass of the aircraft

FZAM - Aerodynamic force in the Z-direction divided by the mass of the aircraft

FZWM - Force in the Z-direction of the wind axis divided by the mass of the aircraft

G - Acceleration due to gravity

GEE - Scaled acceleration due to gravity

GS - Glide slope in degrees

GSO - Optimal glide slope

H - Graphic transformation matrix (H-Matrix) or array

H1 - First component array of the H-Matrix

H2 - Second component array of the H-Matrix

H3 - Third component array of the H-Matrix

HHnn - Scalar equivalent of the H-Matrix or array

HINSCT - Horizontal intersection of a line, used in the software window

HMIR - Height of Lens below the landing surface

I - Integer variable usually a counter

IA - Do-loop counter based on angle of attack

IAGN - A counter to check the number of times a point has gone through the software window

IALPHA - Integer conversion of ALPHA

IARG - Integer conversion of ARG

IB - Do-loop counter based on the side slip angle

IBETA - Integer conversion of BETA

ICHOYC - Integer conversion of CHOYC

IDE - Graphic array containing the dynamic portion of the display

IDEV - Graphic device number (1 or 2)

IDIR - Graphic block directory for the graphics digital processor

IDON - Array of packed points for the donut portion of the indexer

IER - Error flag returned by graphic subroutines

IFAST - Packed graphic array of the fast cheveron

IPLS - Integer counter equal to I plus one

ISF7 - Integer scale factor based on thrust divided by mass

ISLO - Packed graphic array of the slow cheveron

ISQ - Array/graphics block of fixed data, basically the square or window

ITDIR - Text directory for the graphics digital processor

ITEXnn - Line of text that is sent from the digital computer to the graphic digital processor

IWIRE - Wire caught on arrested landing

IX - Operating values of start/end points (X-coordinate) used in software window

IX1 - Equivalent of XSTART, used in software window

IX2 - Equivalent of XEND, used in software window

IY - Operating values of start/end points (Y-coordinate), used in software

IY1 - Equivalent of YSTART, used in software window

IY2 - Equivalent of YEND , used in software window

J - Do-loop counter

KK - Array of integers used in outputting coefficients

KPOT - Array of integers used in outputing analog pot settings

LL - Landing result flag

NAD - Number of analog to digital conversion variables/trunk lines

ND - Display flag based on present condition of the angle of attack indexer

NDA - Number of digital to analog conversion variables/trunk lines

NULL - Octal value used to null out a line of text

P - Angular velocity of the aircraft about X-axis

Pn - Array of runway points

PDOTN - The negative of the time derivitive of P

POT - Array of pot settings for the analog

PPnn - Scalar equivalents of Pn

PS - P about the stability axis

PSB - PS normalized

Q - Angular velocity of the aircraft about the Y-axis

QDOTN - The negative of the time derivitive of Q

QS - Q about the stability axis

QSB - QS normalized

QUE - Dynamic pressure

R - Angular velocity about the Z-axis

RAMP - X-coordinate of the ramp of the runway

RDOTN - The negative of the time derivitative of R

RHO - Density of air

RIXX - Moment of inertia of the aircraft about the X-axis

RIXZ - Product of inertia about the X and Z-axis

RIYY - Moment of inertia of the aircraft about the Z-axis

RMASS - Mass of the aircraft

RS - R about the stability axis

RSB - RS normalized

S - Wing area of the aircraft

SA - Array of sines of the angle array A

SDOT - Array of time derivitives (velocities) of the distances in all three inertial directions

SF1 - Scale factor based on maximum velocity in X-direction

SF2 - Scale factor based on maximum velocity in Y-direction

SF3 - Scale factor based on maximum velocity in Z-direction

SF4 - Scale factor based on maximum angular velocity in X-direction

SF5 - Scale factor based on maximum angular velocity in Y-direction

SF6 - Scale factor based on the maximum angular velocity in the Z-direction

SF7 - Scale factor based on thrust divided by mass of the aircraft

SF8 - Scale factor based on maximum angle of attack

SF9 - Scale factor based on the maximum side slip angle

SF10 - Scale factor based on the maximum yaw angle

SF11 - Scale factor based on the maximum pitch angle

SF12 - Scale factor based on the maximum roll angle

SF13 - Scale factor based on the maximum distance in the X-direction

SF14 - Scale factor based on the maximum distance in the Y-direction

SF15 - Scale factor based on the maximum distance in the Z-direction

SF16 - Scale factor based on the maximum flying tail deflection angle

SF17 - Scale factor based on the maximum aileron deflection angle

SF18 - Scale factor based on the maximum rudder deflection angle

SF19 - Scale factor based on the density of air

SF20 - Scale factor based on SF1 squared divided by SF19

SF21 - Ratio of SF6 to SF4

SF22 - Ratio of SF1 to SF4

SF23 - Ratio of SF1 to SF5

SF24 - Ratio of SF1 to SF6

SF25 - Ratio of SF4 to SF5

SF26 - Ratio of SF5 to SF6

SF27 - SF4 squared

SF28 - SF5 squared

SF29 - SF6 squared

SF30 - Feedback gain for yaw damper

SF31 - Scale factor based on SF7 divided by SF1 and SF5

SF32 - Scale factor based on SF7 divided by SF1 and SF6

SF33 - Ratio of SF1 to SF2

SF34 - Ratio of SF1 to SF3

SF35 - Scale factor based on ratio of SF5 to SF8

SF36 - Scale factor based on ratio of SF6 to SF9

SF37 - Scale factor based on ratio of SF6 to SF10

SF38 - Scale factor based on ratio of SF5 to SF11

SF39 - Scale factor based on ratio of SF4 to SF12

SF40 - Ratio of SF7 to SF1

SFA - Array of scale factors, made up to SF8 through SF12

SFACTR - Scale factor of the H-Matrix

SLOPE - Slope of a display line, used in software window

SNKRT - Sink rate of the aircraft in ft/sec at the conclusion of a run

SSAn - Scalar equivalents of SA

SX - Actual distance of aircraft in X-direction (inertial)

SXO - Initial condition on SX

SXN - Nromalized Distance of aircraft in X-direction (inertial)

SY - Actual distance of aircraft in Y-direction (inertial)

SYN - Normalized distance of aircraft in Y-direction (inertial)

SZ - Actual distance of aircraft in Z-direction (inertial)

SZO - Initial condition on SZ

SZN - Final cutoff value on SZ (height of eye)

T - Thrust of the aircraft

TALPHA - Tangent of the yaw angle

TAU - Time delay of the prediction and update

TM - Thrust divided by mass of aircraft

TPn - Temporary point number n

TRIG - Array of sines of various angles

TX - X-direction value used to chop the runway

V - Velocity

VO - Initial condition on velocity V

VDOT - Time derivitive of V

VDOTO - VDOT of the iteration before

VINSCT - Vertical intersection of a line, used in window

W - Weight of the aircraft

Wn - Wire position on runway

WIND - Velocity of the wind in knots

X - X value used in software window

XEND - Array of X-coordinate ending points of display lines

XMIR - X position of the lens

XSTART - Array of X-coordinate starting points of display lines

XTEMP - Temporary storage for X

Y - Y value used in software window

YEND - Array of Y-coordinate ending points of display lines

YMB - Y-coordinate of the "meatball"

YMID - Y intercept of the horizon

YO - H-Matrix offset in Y-direction

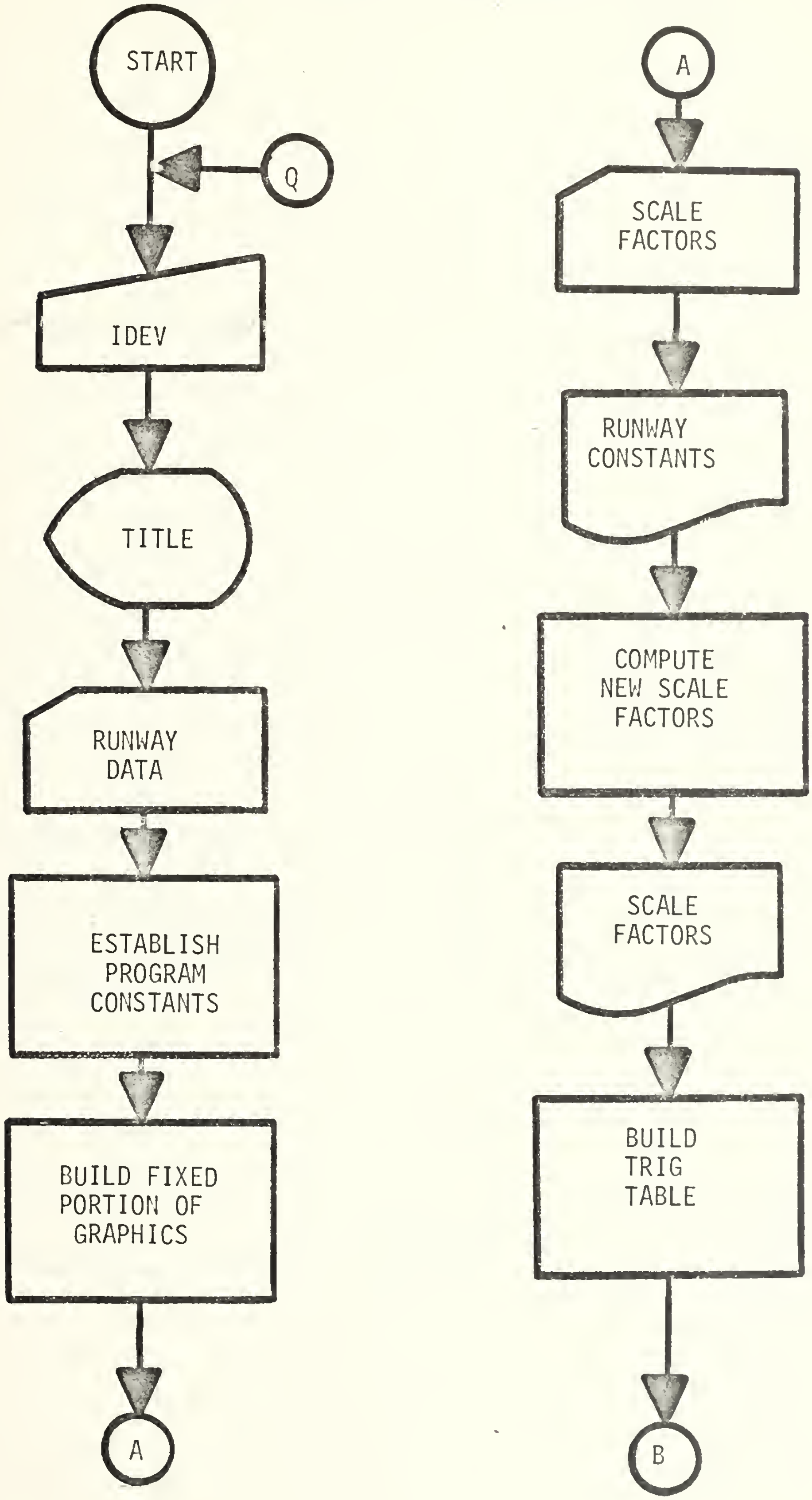
YSTART - Array of Y-coordinate starting points of display lines

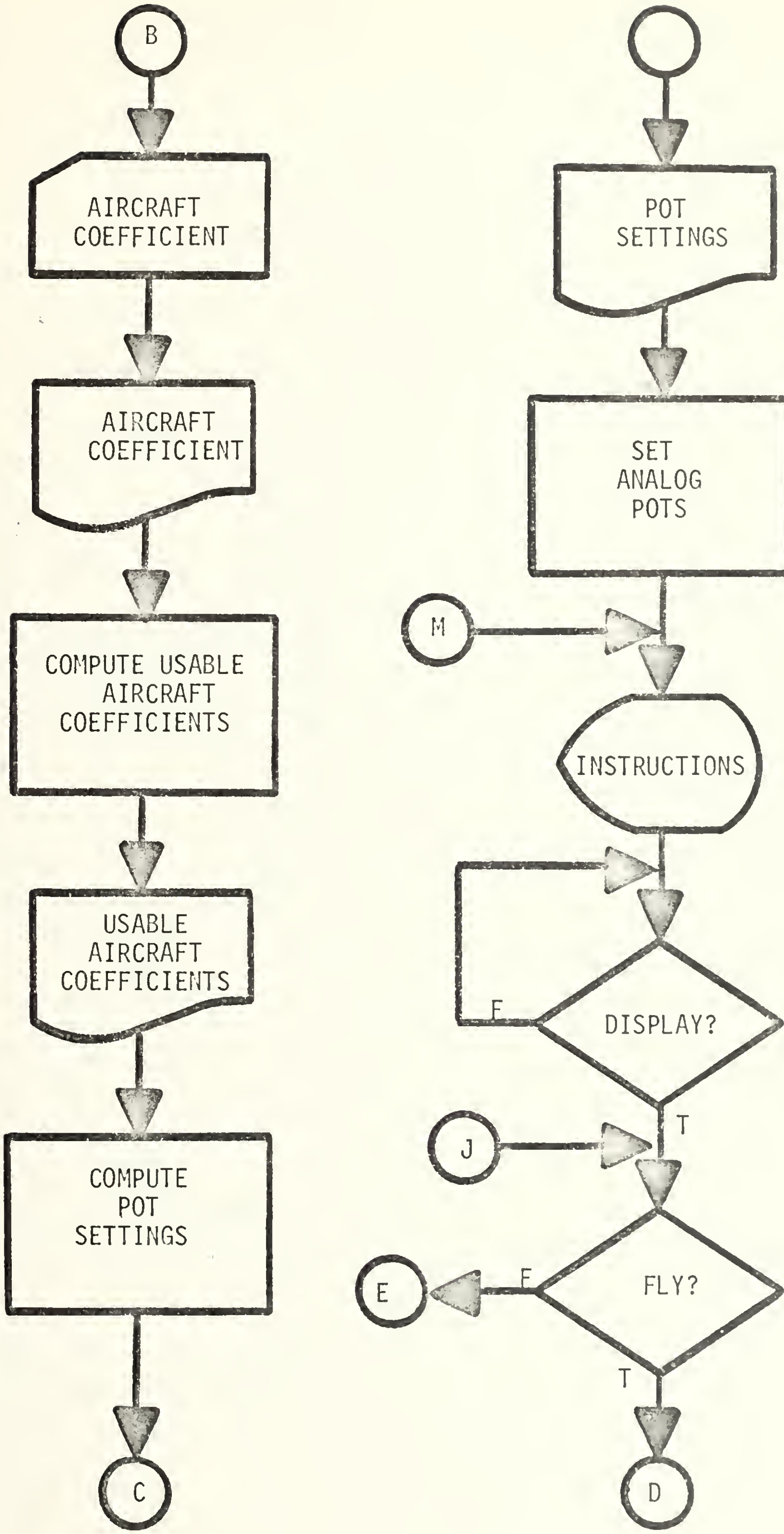
YTEMP - Temporary storage for Y-coordinate in software window

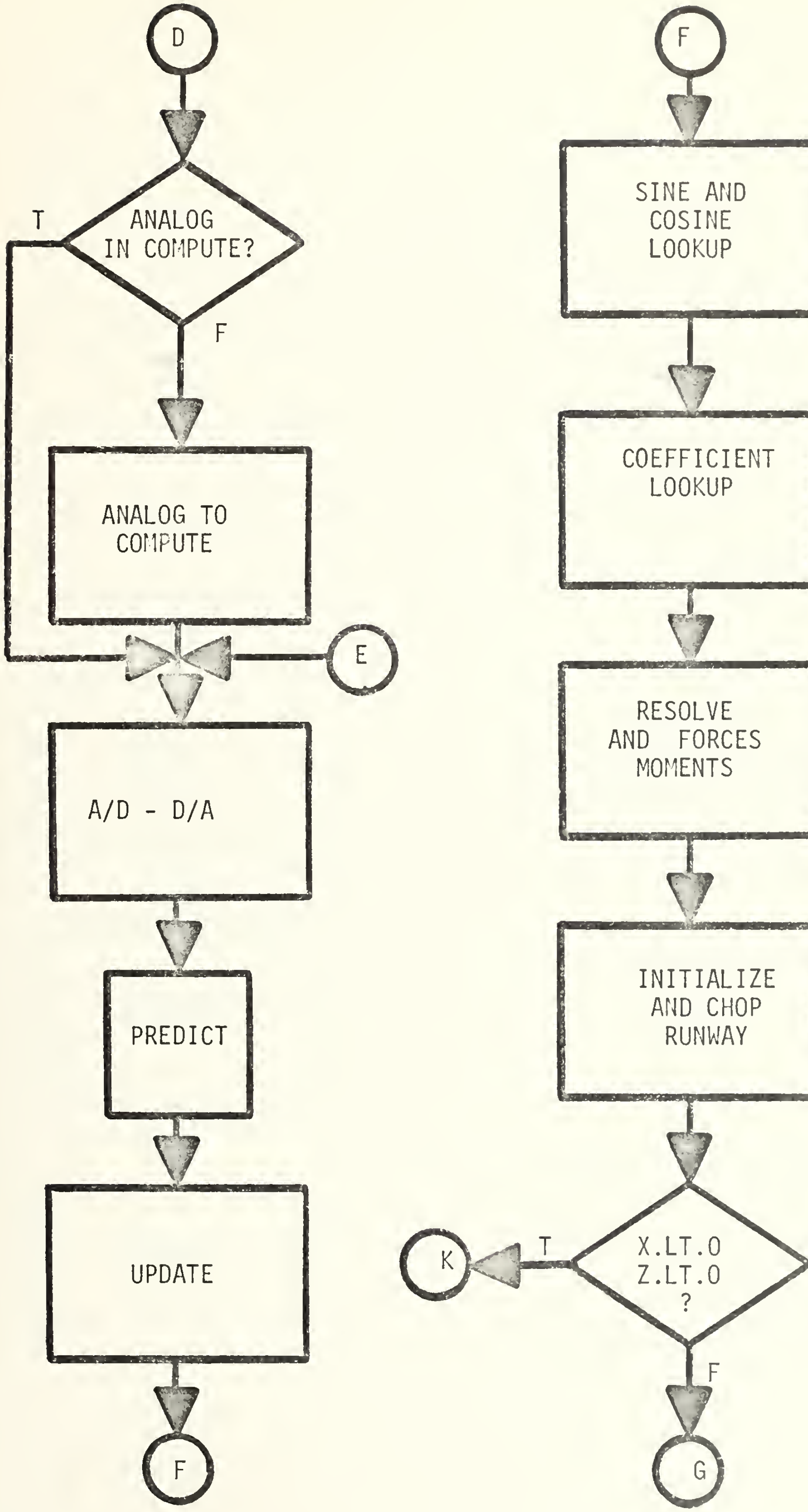
Z - Temporary storage array used in multiplying H1, H2, and H2 to yield the H-Matrix

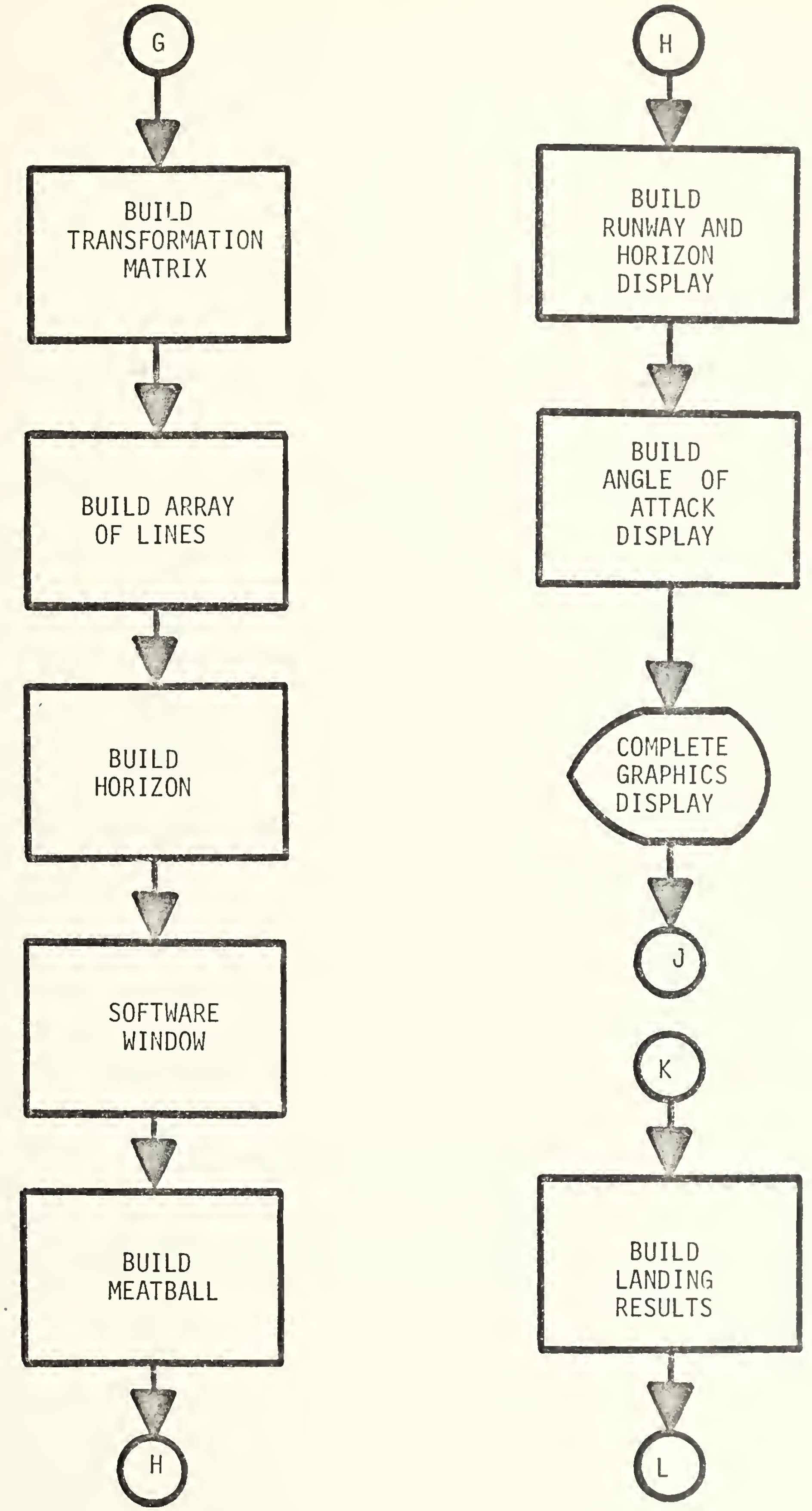
ZO - H-Matrix offset in Z-direction

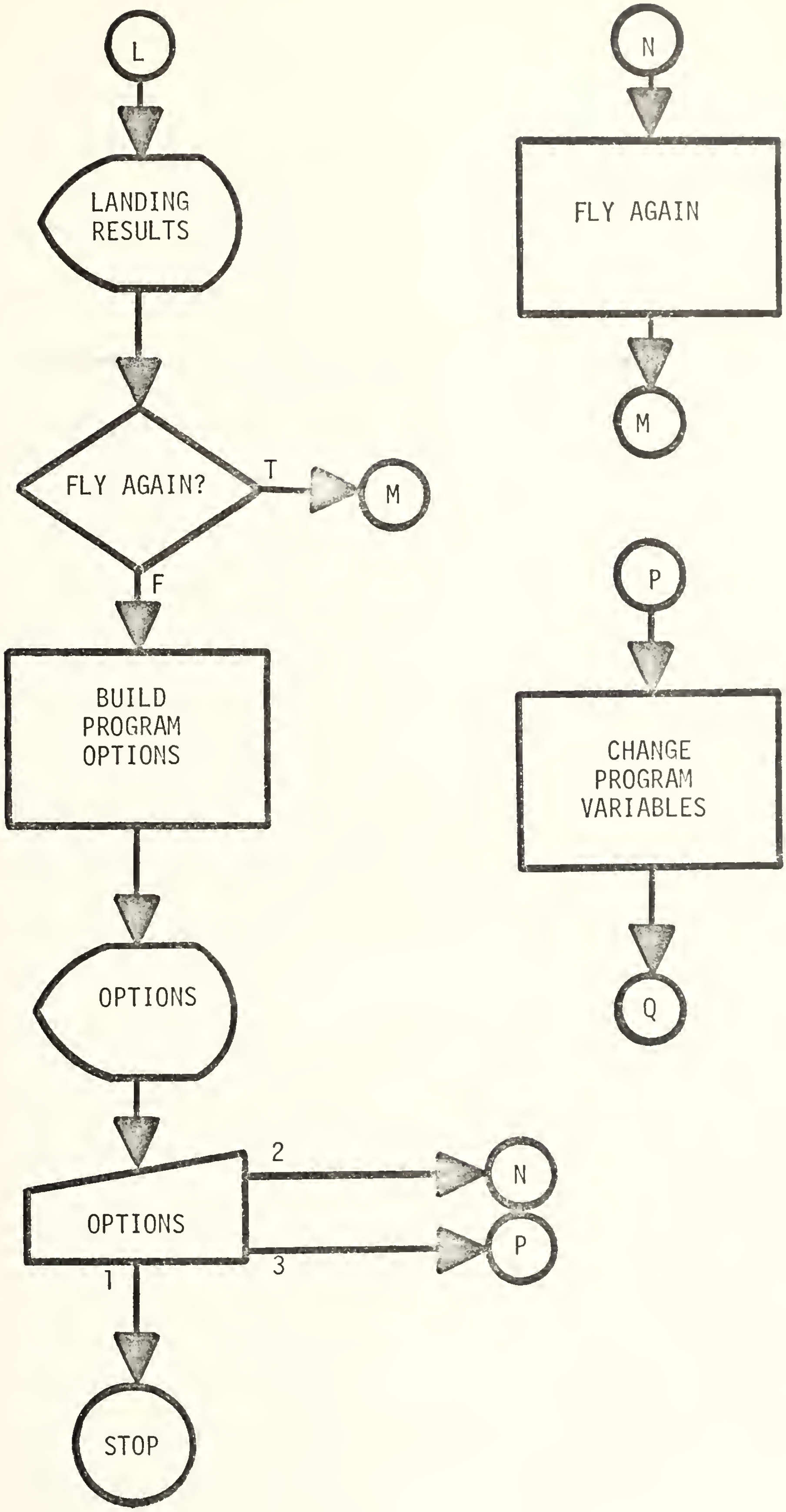
APPENDIX D - DIGITAL PROGRAM FLOW DIAGRAM




B
AIRCRAFT COEFFICIENT
AIRCRAFT COEFFICIENT
COMPUTE USABLE AIRCRAFT COEFFICIENTS
USABLE AIRCRAFT COEFFICIENTS
COMPUTE POT SETTINGS
C
POT SETTINGS
SET ANALOG POTS
M
INSTRUCTIONS
F
DISPLAY?
T
J
E
F
FLY?
T
D


D
ANALOG IN COMPUTE?
T
F
ANALOG TO COMPUTE
E
A/D - D/A
PREDICT
UPDATE
F
F
SINE AND COSINE LOOKUP
COEFFICIENT LOOKUP
RESOLVE AND FORCES MOMENTS
INITIALIZE AND CHOP RUNWAY
X.LT.0 Z.LT.0 ?
T
K
F
G


G
BUILD TRANSFORMATION MATRIX
BUILD ARRAY OF LINES
BUILD HORIZON
SOFTWARE WINDOW
BUILD MEATBALL
H
H
BUILD RUNWAY AND HORIZON DISPLAY
BUILD ANGLE OF ATTACK DISPLAY
COMPLETE GRAPHICS DISPLAY
J
K
BUILD LANDING RESULTS
L


L
LANDING RESULTS
FLY AGAIN?
T
M
F
BUILD PROGRAM OPTIONS
OPTIONS
OPTIONS
2
N
3
P
1
STOP
N
FLY AGAIN
M
P
CHANGE PROGRAM VARIABLES
Q

APPENDIX E - OPERATING MANUAL

The program exists on tape in two forms, one is in a Source deck format (SI) and must be compiled prior to execution. This takes approximately 15 minutes. This tape is stored in the tape locker and is titled CALS NEW VERSION. The other version is a core dump (SAVE) version. Just prior to the execution of the program, after the compilation and loading phases are complete, a copy of core is dumped on tape. Execution of this version (RERUN) is approximately 10 seconds. Again this is stored in the tape locker under the title of CALS CORE DUMP.

All the required cards for the program are filed in the file under CARRIER APPROACH LANDING SIMULATOR. The cards filed include the master version of the program, several data decks and the control cards for running any of the different programs. The control cards are color coded with explanations of their use written on each set.

The instructions for operating the digital computer and graphics display are already published and can be obtained from the Laboratory Office.

The following is a sequence of events and instructions for operating the simulator assuming all equipment is turned on.

1. Load the version of tape selected on the tape drives. Select the proper mount (2 for SI, 3 for RERUN).
2. Load and ready the card reader with control cards followed by the DATA.
3. Ready the Line Printer.
4. On the Digital Main Frame, Punch IDLE, RESET, RUN, CARDS. Cards and tape should start being read at this time.

5. Load the Analog Program board and the Analog Logic board into the computer (Boards number 7).
6. On the Analog Keyboard punch KEYBOARD, LOCAL, POTSET. In the far right control box, only the following can be lit: IDCX1 or IDCX.1 and REAL TIME. All other lights must be punched out. When complete punch DIGITAL CMPTR.
7. On the Analog the following options exist:

   DSO - UP - no printed output

   CENTER - printed output

   DS1 - UP - distance integrators disabled

   CENTER - distance integrators enabled

   DS2 - UP - yaw damper ON

   CENTER - yaw damper OFF

   DOWN positions on these switches are momentary contact positions.
8. On the Analog:

   Turn the inner dials of DF12 and DF13 clockwise until resistance is felt. Then set the outer dial of DF12 to .1 and the outer dial of DF13 to 10.
9. Under Master Clock (Analog) punch RUN. The run light on the light panel should be on and the DF13 light should be flashing.
10. At the Graphics terminal teletype to be used (usually number 2), load the controling program by typing

    RESET ("GATD1", 120) !

    If the above is answered with

    FILE NOT FOUND

    type RESET ("GATD1", 20)!

    Then execute the program by typing GATED! At this point nothing should be on the display screen.

11. By this time the Digital computer should have compiled and loaded the main program and the following will be typed out on the Digital consol teletype:

    INPUT AGT NUMBER

    The input light will then come on. To respond, type the AGT number (1 or 2) of the unit being used, followed by a carriage return.
12. The Title should appear on the selected AGT.
13. The Data will be read in from the card reader.
14. If output is selected, the output will be printed on the line printer.
15. The Analog Pots will be set by the Digital computer. The Address and Ratiometer readings should be changing.
16. Set the cockpit in front of the AGT (will only reach AGT-2). The cockpit is stored behind the Analog computer.
17. The Instructions should flash on the screen.
18. Punch the button on the Throttle plate and the display will appear.
19. Punch the button on the control stick to fly. If during a run you wish to abort that run, punch the button on the Throttle plate.
20. At the completion of the run the Landing Results will be displayed, followed by a short delay in which to read them.
21. At this time two options are offered. To fly again punch the button on the Control stick and the program jumps back to the Instructions (#17).

22. To receive the expanded program options, punch the Throttle button. Follow the displayed instructions and type your selection on the AGT teletype unit. This will result in one of three things happening.

    1. Logical STOP to the program.
    2. Jump to the Instructions (#17).
    3. Jump to the selection of the AGR number (#11).

23. At the completion of the computer time. Return all used equipment (cards, tape, boards, cockpit) to their storage locations.

APPENDIX F - PREPARATION OF DATA DECK

The following is a guide to be used in preparing the data deck to be used with the simulator.

Cards 1 - 6 - The first six data cards consist of the actual coordinates of the six runway points. The first ten columns of the card are the x coordinate in feet, the second ten columns are the y coordinate in feet, the third ten columns are the z coordinate in feet and the next ten columns are the H-Matrix scale factor which in this simulator is 1.0. The remaining columns are left blank. The order of the runway points is as follows: far-centerline, far-left, near-left, near-centerline, near-right, far-right.

Card 7 - The first ten columns consist of the optimum glide slope (GSO) in degrees. The second ten columns contain the x coordinate of the location of the Fresnel Lens (XMIR) in feet. The third ten columns contain the velocity of the headwind (WIND) in knots.

Card 8 - 10 - These cards contain the inputed scale factors for the scaling of the analog solution. Each scale factor has a field of ten columns and are ordered as follows:

Card 8 - SF1, SF2, SF3, SF4, SF5, SF6, SF8, SF9

Card 9 - SF10, SF11, SF12, SF13, SF14, SF15, SF16, SF17

Card 10 - SF18, SF19, SF30, the remaining columns are blank

Card 11 - This card contains the initial conditions of the problem in ten column increments as follows: initial x coordinate (SXO) in feet, initial altitude (SZO) in feet, initial velcoity (VO) in ft/sec, initial angle of attack (A1O) in degrees, initial elevator angle (DITO) in degrees and the density of the air (RHO) in slug/ft^3. The remaining portion of the card is left blank.

Card 12 - This card contains a portion of the aircraft constants again in ten column intervals. They are as follows: weight (W) of the aircraft in lb, wing span (B) in ft, wing chord (CB) in ft, wing area (S) in ft^2, moment of inertia about the x axis (RIXX) in slug-ft^2, moment of inertial about the y axis (RIYY) in slug-ft^2, moment of inertia about the z axis (RIZZ) in slug-ft^2, and the cross product of inertia (RIXZ) in slug-ft^2.

Card 13 - This card contains some more aircraft constants again in ten column intervals. They are as follows: maximum thrust (T) in lbs, optimum/landing angle of attack (AOALDG) in degrees, height of eye at touchdown (SZF) in feet. The remaining columns are left blank.

Cards 14 - 85 (Alternating) - These cards contain the aerodynamic coefficients dependent on both alpha and beta. The first card in the series is as follows: in columns 1-2 the coefficient number, columns 3-4 blank, column 5 the index on beta (IB), colums 6-10 blank. On the remaining portion of the card in ten column intervals are the coefficients indexed on alpha (IA). The second card in the series also contains the remaining coefficients again in ten column intervals and indexed on alpha. Alpha is indexed 15 times for each beta index while beta is indexed 9 times for each of the four coefficients. The range on alpha is -25 degrees to + 45 degrees with 5 degree intervals while the range on beta is -40 degrees to +40 degrees with 10 degree intervals.

The coefficients are as follows:

Number	Coefficient
1	C_l
2	C_m
3	C_n
4	C_Y

Cards 86 - 125 (Alternating) - These cards contain the aerodynamic coefficients dependent only on alpha. The first card in the series is as follows: columns 1-2 the coefficient number, columns 3-10 blank. The remaining portion of the card in ten column intervals are the aerodynamic coefficients indexed on alpha. The second card of the series contains the remaining coefficients again in ten column intervals and indexed on alpha. Alpha is indexed 15 times for each of the coefficients. A list of the remining coefficients and their numbers is given below.

Number	Coefficient
5	C_D
6	C_L
7	$C_{L_{\delta it}}$
8	$C_{m_{\delta it}}$
9	$C_{Y_{\delta r}}$
10	$C_{l_{\delta r}}$
11	$C_{n_{\delta r}}$
12	$C_{Y_{\delta a}}$
13	$C_{l_{\delta a}}$
14	$C_{n_{\delta a}}$
15	C_{Y_P}
16	C_{l_P}
17	C_{n_P}
18	C_{Y_R}
19	C_{l_R}

Number	Coefficient
20	C_{n_R}
21	C_{L_Q}
22	C_{m_Q}
23	$C_{L_{\dot{\alpha}}}$
24	$C_{m_{\dot{\alpha}}}$

APPENDIX G - SAMPLE OUTPUT

The following is a sample output of the digital program and contains the following sections:

1. Runway Constants
2. Scale Factors and Aircraft Constants
3. Original Aircraft Aerodynamic Coefficients
4. Usable Aircraft Aerodynamic Coefficients
5. Pot Settings for the Analog Computer
6. Output of the Amplifiers and D/A Trunks

RUNWAY CØNSTANTS

PØINT	X	Y	Z
1	.0	.0	.0
2	.0	-100.0	.0
3	8000.0	-100.0	.0
4	8000.0	.0	.0
5	8000.0	100.0	.0
6	.0	100.0	.0

```
XMIR =  7300.000
HMIR =     6.530
GSØ  =  -  3.250
RAMP =  8000.000
W1   =  7674.327
W2   =  7641.327
W3   =  7608.327
W4   =  7575.327
```

```
SF1    =    400.000
SF2    =    400.000
SF3    =    400.000
SF4    =      2.000
SF5    =      2.000
SF6    =      2.000
SF7    =     20.000
SF8    =     45.000
SF9    =     45.000
SF10   =     85.000
SF11   =     85.000
SF12   =     85.000
SF13   =  30000.000
SF14   =   4000.000
SF15   =   2000.000
SF16   =     10.000
SF17   =      5.000
SF18   =      5.000
SF19   =    400.000
SF20   =    200.000
SF21   =      1.000
SF22   =    200.000
SF23   =    200.000
SF24   =    200.000
SF25   =      1.000
SF26   =      1.000
SF27   =      4.000
SF28   =      4.000
SF29   =      4.000
A0ALDG =     10.000
```

```
SF30   =      1.000
SF31   =       .025
SF32   =       .025
SF33   =      1.000
SF34   =      1.000
SF35   =      2.546
SF36   =      2.546
SF37   =      1.348
SF38   =      1.348
SF39   =      1.348
SF40   =       .050

SX0    =  28000.000
SZ0    =   1200.000
V0     =    250.000
A10    =      4.510
DITO   =     -3.410
RH0    =     .00238
WIND   =     10.000

W      =  18085.000
B      =     38.730
CB     =     10.840
S      =    375.000
RIXX   =  12645.000
RIYY   =  58295.000
RIZZ   =  65754.000
RIXZ   =   -208.000
T      =  10000.000
SZF    =     12.000
```

ORIGINAL COEF ARRAY .

COEFFICIENT NUMBER 1

BETA ALPHA	-40.0	-30.0	-20.0	-10.0	.0	10.0	20.0	30.0	40.0
-25.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
-20.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
-15.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
-10.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
-5.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
5.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
10.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
15.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
20.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
25.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
30.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
35.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
40.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599
45.0	.0965599	.0724199	.0482800	.0241400	.0000000	-.0241400	-.0482800	-.0724199	-.0965599

ØRIGINAL CØEF ARRAY

COEFFICIENT NUMBER 2

BETA / ALPHA	-40.0	-30.0	-20.0	-10.0	.0	10.0	20.0	30.0	40.0
-25.0	.2639960	.2639960	.2639960	.2639960	.2639960	.2639960	.2639960	.2639960	.2639960
-20.0	.2108960	.2108960	.2108960	.2108960	.2108960	.2108960	.2108960	.2108960	.2108960
-15.0	.1577960	.1577960	.1577960	.1577960	.1577960	.1577960	.1577960	.1577960	.1577960
-10.0	.1046961	.1046961	.1046961	.1046961	.1046961	.1046961	.1046961	.1046961	.1046961
-5.0	.0515961	.0515961	.0515961	.0515961	.0515961	.0515961	.0515961	.0515961	.0515961
.0	-.0015038	-.0015038	-.0015038	-.0015038	-.0015038	-.0015038	-.0015038	-.0015038	-.0015038
5.0	-.0546038	-.0546038	-.0546038	-.0546038	-.0546038	-.0546038	-.0546038	-.0546038	-.0546038
10.0	-.1077037	-.1077037	-.1077037	-.1077037	-.1077037	-.1077037	-.1077037	-.1077037	-.1077037
15.0	-.1608037	-.1608037	-.1608037	-.1608037	-.1608037	-.1608037	-.1608037	-.1608037	-.1608037
20.0	-.2139037	-.2139037	-.2139037	-.2139037	-.2139037	-.2139037	-.2139037	-.2139037	-.2139037
25.0	-.2670036	-.2670036	-.2670036	-.2670036	-.2670036	-.2670036	-.2670036	-.2670036	-.2670036
30.0	-.3201036	-.3201036	-.3201036	-.3201036	-.3201036	-.3201036	-.3201036	-.3201036	-.3201036
35.0	-.3732036	-.3732036	-.3732036	-.3732036	-.3732036	-.3732036	-.3732036	-.3732036	-.3732036
40.0	-.4263036	-.4263036	-.4263036	-.4263036	-.4263036	-.4263036	-.4263036	-.4263036	-.4263036
45.0	-.4794036	-.4794036	-.4794036	-.4794036	-.4794036	-.4794036	-.4794036	-.4794036	-.4794036

ORIGINAL COEF ARRAY

COEFFICIENT NUMBER 3

BETA / ALPHA	-40.0	-30.0	-20.0	-10.0	.0	10.0	20.0	30.0	40.0
-25.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
-20.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
-15.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
-10.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
-5.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
5.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
10.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
15.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
20.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
25.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
30.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
35.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
40.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199
45.0	-.1119199	-.0839400	-.0559600	-.0279800	.0000000	.0279800	.0559600	.0839400	.1119199

ORIGINAL COEF ARRAY

COEFFICIENT NUMBER 4

BETA / ALPHA	-40.0	-30.0	-20.0	-10.0	.0	10.0	20.0	30.0	40.0
-25.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
-20.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
-15.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
-10.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
-5.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
5.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
10.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
15.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
20.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
25.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
30.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
35.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
40.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993
45.0	1.0015993	.7511999	.5007999	.2503999	.0000000	-.2503999	-.5007999	-.7511999	-1.0015993

ORIGINAL COEF ARRAYS

ALPHA	COEFFICIENT NUMBER 5	COEFFICIENT NUMBER 6	COEFFICIENT NUMBER 7	COEFFICIENT NUMBER 8	COEFFICIENT NUMBER 9
-25.0	.0789612	-1.3319769	.0110000	-.0145000	.0045000
-20.0	.0911161	-.9919785	.0110000	-.0145000	.0045000
-15.0	.1032711	-.6519783	.0110000	-.0145000	.0045000
-10.0	.1154261	-.3119794	.0110000	-.0145000	.0045000
-5.0	.1275811	.0280204	.0110000	-.0145000	.0045000
.0	.1397361	.3680202	.0110000	-.0145000	.0045000
5.0	.1518911	.7080200	.0110000	-.0145000	.0045000
10.0	.1640461	1.0480194	.0110000	-.0145000	.0045000
15.0	.1762011	1.3880196	.0110000	-.0145000	.0045000
20.0	.1883562	1.7280188	.0110000	-.0145000	.0045000
25.0	.2005111	2.0680180	.0110000	-.0145000	.0045000
30.0	.2126661	2.4080172	.0110000	-.0145000	.0045000
35.0	.2248211	2.7480173	.0110000	-.0145000	.0045000
40.0	.2369761	3.0880175	.0110000	-.0145000	.0045000
45.0	.2491311	3.4280167	.0110000	-.0145000	.0045000

ORIGINAL COEF ARRAYS

ALPHA	COEFFICIENT NUMBER 10	COEFFICIENT NUMBER 11	COEFFICIENT NUMBER 12	COEFFICIENT NUMBER 13	COEFFICIENT NUMBER 14
-25.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
-20.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
-15.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
-10.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
-5.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
5.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
10.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
15.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
20.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
25.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
30.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
35.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
40.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237
45.0	.0005021	-.0019800	.0025500	-.0029950	-.0008237

ORIGINAL COEF ARRAYS

ALPHA	COEFFICIENT NUMBER 15	COEFFICIENT NUMBER 16	COEFFICIENT NUMBER 17	COEFFICIENT NUMBER 18	COEFFICIENT NUMBER 19
-25.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
-20.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
-15.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
-10.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
-5.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
5.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
10.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
15.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
20.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
25.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
30.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
35.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
40.0	.1436000	-.3550000	-.1117000	.4559000	.1328000
45.0	.1436000	-.3550000	-.1117000	.4559000	.1328000

ORIGINAL COEF ARRAYS

ALPHA	COEFFICIENT NUMBER 20	COEFFICIENT NUMBER 21	COEFFICIENT NUMBER 22	COEFFICIENT NUMBER 23	COEFFICIENT NUMBER 24
-25.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
-20.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
-15.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
-10.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
-5.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
5.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
10.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
15.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
20.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
25.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
30.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
35.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
40.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000
45.0	-.3469999	.0000000	-3.8999996	.0000000	-.7490000

USABLE COEF ARRAY

COEFFICIENT NUMBER 1

BETA ALPHA	-40.0	-30.0	-20.0	-10.0	.0	10.0	20.0	30.0	40.0
-25.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
-20.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
-15.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
-10.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
-5.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
5.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
10.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
15.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
20.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
25.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
30.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
35.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
40.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217
45.0	5.5453217	4.1589898	2.7726637	1.3863319	.0000000	-1.3863319	-2.7726637	-4.1589898	-5.5453217

USABLE COFF ARRAY

COEFFICIENT NUMBER 2

BETA / ALPHA	-40.0	-30.0	-20.0	-10.0	.0	10.0	20.0	30.0	40.0
-25.0	.9204424	.9204424	.9204424	.9204424	.9204424	.9204424	.9204424	.9204424	.9204424
-20.0	.7353051	.7353051	.7353051	.7353051	.7353051	.7353051	.7353051	.7353051	.7353051
-15.0	.5501679	.5501679	.5501679	.5501679	.5501679	.5501679	.5501679	.5501679	.5501679
-10.0	.3650310	.3650310	.3650310	.3650310	.3650310	.3650310	.3650310	.3650310	.3650310
-5.0	.1798938	.1798938	.1798938	.1798938	.1798938	.1798938	.1798938	.1798938	.1798938
.0	-.0052431	-.0052431	-.0052431	-.0052431	-.0052431	-.0052431	-.0052431	-.0052431	-.0052431
5.0	-.1903803	-.1903803	-.1903803	-.1903803	-.1903803	-.1903803	-.1903803	-.1903803	-.1903803
10.0	-.3755172	-.3755172	-.3755172	-.3755172	-.3755172	-.3755172	-.3755172	-.3755172	-.3755172
15.0	-.5606545	-.5606545	-.5606545	-.5606545	-.5606545	-.5606545	-.5606545	-.5606545	-.5606545
20.0	-.7457917	-.7457917	-.7457917	-.7457917	-.7457917	-.7457917	-.7457917	-.7457917	-.7457917
25.0	-.9309286	-.9309286	-.9309286	-.9309286	-.9309286	-.9309286	-.9309286	-.9309286	-.9309286
30.0	-1.1160658	-1.1160658	-1.1160658	-1.1160658	-1.1160658	-1.1160658	-1.1160658	-1.1160658	-1.1160658
35.0	-1.3012030	-1.3012030	-1.3012030	-1.3012030	-1.3012030	-1.3012030	-1.3012030	-1.3012030	-1.3012030
40.0	-1.4863403	-1.4863403	-1.4863403	-1.4863403	-1.4863403	-1.4863403	-1.4863403	-1.4863403	-1.4863403
45.0	-1.6714775	-1.6714775	-1.6714775	-1.6714775	-1.6714775	-1.6714775	-1.6714775	-1.6714775	-1.6714775

USABLE COEF ARRAY

COEFFICIENT NUMBER 3

BETA ALPHA	-40.0	-30.0	-20.0	-10.0	.0	10.0	20.0	30.0	40.0
-25.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
-20.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
-15.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
-10.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
-5.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
5.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
10.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
15.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
20.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
25.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
30.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
35.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
40.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439
45.0	-1.2360439	-.9270338	-.6180225	-.3090113	.0000000	.3090113	.6180225	.9270338	1.2360439

USABLE COEF ARRAY

COEFFICIENT NUMBER 4

BETA ALPHA	-40.0	-30.0	-20.0	-10.0	.0	10.0	20.0	30.0	40.0
-25.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
-20.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
-15.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
-10.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
-5.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
5.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
10.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
15.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
20.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
25.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
30.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
35.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
40.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822
45.0	6.6874822	5.0156145	3.3437428	1.6718710	.0000000	-1.6718710	-3.3437428	-5.0156145	-6.6874822

USABLE COEF ARRAYS

ALPHA	COEFFICIENT NUMBER 5	COEFFICIENT NUMBER 6	COEFFICIENT NUMBER 7	COEFFICIENT NUMBER 8	COEFFICIENT NUMBER 9
-25.0	-.5272085	8.8933487	-.7344484	-.5055536	.1502281
-20.0	-.6083643	6.6232460	-.7344484	-.5055536	.1502281
-15.0	-.6895209	4.3531313	-.7344484	-.5055536	.1502281
-10.0	-.7706774	2.0830253	-.7344484	-.5055536	.1502281
-5.0	-.8518340	-.1870867	-.7344484	-.5055536	.1502281
.0	-.9329905	-2.4571987	-.7344484	-.5055536	.1502281
5.0	-1.0141471	-4.7273108	-.7344484	-.5055536	.1502281
10.0	-1.0953037	-6.9974201	-.7344484	-.5055536	.1502281
15.0	-1.1764602	-9.2675348	-.7344484	-.5055536	.1502281
20.0	-1.2576174	11.5376428	-.7344484	-.5055536	.1502281
25.0	-1.3387733	13.8077508	-.7344484	-.5055536	.1502281
30.0	-1.4199299	16.0778588	-.7344484	-.5055536	.1502281
35.0	-1.5010864	18.3479728	-.7344484	-.5055536	.1502281
40.0	-1.5822430	20.6180875	-.7344484	-.5055536	.1502281
45.0	-1.6633995	22.8881956	-.7344484	-.5055536	.1502281

USABLE COEF ARRAYS

ALPHA	COEFFICIENT NUMBER 10	COEFFICIENT NUMBER 11	COEFFICIENT NUMBER 12	COEFFICIENT NUMBER 13	COEFFICIENT NUMBER 14
-25.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
-20.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
-15.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
-10.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
-5.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
5.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
10.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
15.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
20.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
25.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
30.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
35.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
40.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847
45.0	.1441751	-.1093356	.0851293	-.8599967	-.0454847

USABLE COEF ARRAYS

ALPHA	COEFFICIENT NUMBER 15	COEFFICIENT NUMBER 16	COEFFICIENT NUMBER 17	COEFFICIENT NUMBER 18	COEFFICIENT NUMBER 19
-25.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
-20.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
-15.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
-10.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
-5.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
5.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
10.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
15.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
20.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
25.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
30.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
35.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
40.0	.0047939	-.1019362	-.0061681	.0152198	.0381327
45.0	.0047939	-.1019362	-.0061681	.0152198	.0381327

USABLE COEF ARRAYS

ALPHA	COEFFICIENT NUMBER 20	COEFFICIENT NUMBER 21	COEFFICIENT NUMBER 22	COEFFICIENT NUMBER 23	COEFFICIENT NUMBER 24
-25.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
-20.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
-15.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
-10.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
-5.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
5.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
10.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
15.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
20.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
25.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
30.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
35.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
40.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572
45.0	-.0191613	.0000000	-.0679882	.0000000	-.0130572

PØT SETTINGS

PØT(0)	= .01645	PØT(24)	= .13481
PØT(1)	= .05899	PØT(25)	= .25465
PØT(2)	= .20000	PØT(26)	= .25465
PØT(3)	= .00357	PØT(27)	= .13481
PØT(4)	= .09110	PØT(30)	= .13481
PØT(5)	= .20000	PØT(31)	= .05000
PØT(6)	= .00316	PØT(32)	= .62500
PØT(7)	= .06943	PØT(33)	= .95200
PØT(10)	= .20000	PØT(34)	= .17452
PØT(11)	= .10000	PØT(35)	= .18399
PØT(12)	= .10000	PØT(36)	= .00160
PØT(13)	= .32700	PØT(37)	= .23068
PØT(14)	= .28119	PØT(40)	= .09620
PØT(15)	= .02600	PØT(41)	= .28000
PØT(16)	= .93333	PØT(42)	= .10022
PØT(17)	= .50000	PØT(43)	= .22918
PØT(20)	= .60000	PØT(44)	= .34100
PØT(21)	= .01333	PØT(45)	= .10000
PØT(22)	= .10000	PØT(46)	= .00056
PØT(23)	= .20000	PØT(50)	= .00600

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T431 INDICATES SZDØT/400.     T432 INDICATES AMI/4.00        T433 INDICATES ANI/4.00
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13. ABSTRACT

The following is a report on the design and construction of a fixed-base variable-stability simulator facility combined with the task of landing to a carrier or runway.

The solution was mechanized on a hybrid computer with the analog computer solving the equations of motion and the digital computer used for storage, control and graphics generation. The display was in the form of a computer drawn picture on a graphics terminal. Control was by a simulated cockpit placed in front of the display and connected to the analog computer.

Dynamic validation was considered excellent with the modal periods of the simulated aircraft agreeing very closely with those of the actual aircraft.

The visual display was deemed very good as sufficient visual cues were provided to enable consistent landings by experienced pilots.

This project was undertaken not as a design of a training aid but rather as a research tool for further studies in control systems, human engineering and aircraft dynamics.

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KEY WORDS	LINK A		LINK B		LINK C	
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Aircraft Simulator						
Simulator						
Variable-Stability Simulator						
Interactive Graphics						

Thesis 134945
K108 Kahrs
c.1
A fixed-base variable-stability carrier approach landing simulator (CALS).